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PREFACE

At the opening of the thirty-sixth meeting of ICES the President gave the sad news to the conference that R. S. Clark, D. Sc. was dead. As Dr. Clark had devoted a great part of his life to promoting the work of the Council, and was still very active, being among other things the Chairman of the Consultative Committee, his decease was a great loss not only to the Council, but also in other fields, for instance the herring research.

Dr. Clark had approved all the contributions and prepared this report for printing. It will now be my duty to add some words of introduction.

Since the end of World-War II, a great amount of effort has been devoted to herring research, and several special meetings have been held. The trend has been to conform to a more or less common plan in order to attack the major problems in the biology of this fish. The first of these meetings took place in Copenhagen in October 1945, during the first meeting of the ICES after the war. A herring expert meeting was convened in Aberdeen in May 1946, and a special meeting was arranged to take place in Stockholm in August of that year.

At the annual meeting of the Council in Copenhagen in October 1948, the following recommendation from the Northern North Sea Committee was adopted by the Consultative Committee and passed by the Council:

"The Committee also recommended that a special meeting of Herring Experts be held at the next Council Meeting and should be convened by Dr. R. S. Clark to consider (I) progress on resolutions from the Aberdeen meeting of 1946, (II) fluctuations in the abundance of herring, (III) the marking and migrations of herring, (IV) methods of detection of herring shoals."

However, many of the herring experts found it insufficient to spend half a day only, or, at best, a day, on these extensive problems. Therefore, it was decided later, after some correspondence between Dr. Clark, Mr. Devold, Mr. Friðriksson, the General Secretary, the President, and Mr. Rollefsen, to convene an additional herring expert meeting just before the annual meeting of the Council, on the expenditure of the participants. The present report comprises contributions from both of these meetings which took place during the last days of September and on October 4th 1949 in Edinburgh, and an appendix which was submitted later by its author direct to Dr. Clark and admitted by him.

During the last-mentioned meetings it became evident that a special Herring Committee within the scope of the Council was highly desirable. Following a proposal from the Northern North Sea Committee, a committee of this kind was set up at the Council's meeting in Edinburgh in October 1949.

With the formation of the Herring Committee it will hardly be necessary to convene special meetings of herring experts in the future. Contributions relating to herring research work will very likely be published by this committee. This report will therefore most probably be the last one of its kind.

I should like to take this opportunity of expressing my appreciation of Professor A. C. Hardy's valuable contribution to this report. I find his proposal that an international establishment for the hatching of herring eggs and for ecological studies on the herring should be started, especially interesting and topical. Certainly such an institute would involve considerable expense, both to set up and to maintain, but although such a plan might at first sight seem ambitious, it is by no means unpracticable if its significance is realized and good will is at hand. The nations now participating in the International Council have certainly carried through greater projects by their combined efforts. Perhaps the best procedure would be to establish a kind of "Oceanarium", like the two in Marineland on the eastern coast of Florida (U.S.A.), where it is possible to keep even whales in captivity. Such an "Oceanarium", in connection with smaller pools for hatching and so on, would provide the opportunity for a wide range of experimental work. It is neither necessary nor possible here to propose a working scheme for a "Herring Marine Station", but it seems clear that the following problems would be among the first to be dealt with.

(a) The influence of temperature and other marine factors during the hatching period on the racial characters of the herring.

(b) The physiological conditions of the fish at different stages of maturity, especially the concentration of different salts in the blood.

(c) The effect of currents on fish in different stages of maturity, leading to the solution of problems such as whether the so-called food "migrations" actually exist, or consist only of a passive drift with the prevailing ocean currents.

(d) The nature and formation of herring shoals (formation by supersonic waves (?) etc.).

(e) What does really happen when a spawning migration starts.

There is no doubt that a Herring Marine Station would have many duties to undertake, and I feel it would be a good investment for the herring industry in all countries, as well as for the marine biological research as a whole.

ÁRNI FRIÐRIKSSON.

REPORTER'S RÉSUMÉ

THE meeting was opened by the Convener (Dr. R. S. CLARK) who called upon Mr. DE WATTEVILLE to welcome the experts. The first business was the election of the Chairman for the meeting, and following a proposal by the President of the Council (Dr. ANDERSSON), Dr. CLARK was unanimously elected.

Then followed a discussion on the Progress Reports on the Aberdeen recommendations which were made in 1946. These reports had been submitted by experts before the present meetings began, and it was generally agreed that the progress made has been satisfactory.

The main item of the discussion was paragraph 12 of the 1946 recommendations—the interchange of scale material between different workers.

Mr. LEA (Norway) suggested that every year, representative samples of scales should be taken in addition to the usual research samples and these representative samples should be exchanged. The amount of extra work would not be great. Dr. WOOD (Scotland), suggested that the samples should be restricted to spawning stocks, because, in view of the changing populations in Scottish waters, it would be very difficult to obtain a truly representative sample from the non-spawning shoals. This was agreed upon.

Under paragraph 4, dealing with the measurement of herrings, it was suggested that a renewed effort should be made to get Mr. LEA's measuring device prepared for universal use—especially for the accurate measurement of small herrings.

The charts which had been prepared for the Herring Atlas suggested under paragraph 11 of the Aberdeen recommendations, were presented. As a result of the discussion a sub-committee was formed to decide on the title, and general lay-out of the Atlas, and the languages to be used in the text.

The Atlas will appear as a publication of I.C.E.S., under the main heading of "Fisheries of the NE. Atlantic". The title will be "Herring Atlas" and the sub-title "Fishing Grounds, Landing Ports and Quality".

The languages to be used in the text are English, French and Danish.

The afternoon session of 29. September was devoted to a discussion of herring tagging problems and experiments.

External Tags.

Mr. LEA opened with a general outline of the external tags, his main points being that:

(1) tagging should do no more damage to the herring than can be repaired by the fish itself,
(2) the tags should allow quick healing of the wound and should themselves be immune from attacks by sea water or body fluids,
(3) the tags should be easily seen when the fish is captured.

Mr. LEA presented his Hydrostatic Tag which is so devised that it will not upset the equilibrium of the fish; the buoyancy of this tag enables the wound to heal quickly. He then gave an outline of the results of tagging different fish in Norwegian waters and showed that the Hydrostatic Tag has proved to be superior to other types used in those waters.

Dr. HÖGLUND (Sweden) gave a résumé of the results of tagging experiments (with LEA's tag) in Swedish waters and showed that three fish which had been marked on the Bohuslän coast had made their way westward, two to the Fladen Ground and one to the "Gut". Altogether he had 17 recoveries out of 529 releases.

Internal Tags.

Mr. AASEN (Norway) described in detail the technique of using the internal tag, which is a small metal plate inserted into the body of the herring near the ventral fin, and which is recovered by means of magnets placed in the production line of the meal and oil factories.

Mr. AASEN showed how, by means of tagging, he calculated the minimum speed of one of the herrings to be about 2 knots, and also how a herring which had been tagged in Icelandic waters, had made its way to the west coast of Norway.

Mr. FRIÐRIKSSON (Iceland) pointed out that 21,000 herrings had been tagged in Norway and Iceland and that out of 7,500 Icelandic releases there had been 60 recoveries to date.

Dr. WOOD (Scotland) described his tagging experiments by using a band of plastic material and a small metal identity plate, and pointed out that fish bearing brightly coloured tags might be rather

liable to attacks by gannets. His taggings were also of great interest, in that two out of the four recoveries had made their way from the drift-net grounds to the Fladen Ground.

It was felt that, even though the number of recoveries from these various experiments was small, the general results constituted a contribution of immense importance to herring research, and a sub-committee was appointed to draft a resolution on tagging, and the reward to be paid for recoveries. The proposed resolution was as follows: "That every effort should be made by all countries concerned with Herring Fisheries, to undertake tagging experiments. As the different types of tags become available, it is suggested that each country employs these different types simultaneously in order to test their relative merits. It is also recommended that the reward for returned tagged fish should be the nearest equivalent of 10/–".

On the following day, September 30th, Mr. DEVOLD (Norway) gave a brief account of a scientific cruise in North Atlantic and Arctic waters. He came to the conclusion that the herrings probably followed a special route in their migrations between Norway and Iceland and thought that, if this route could be found, there was a distinct possibility of starting an oceanic fishery for herrings. There was, however, a lack of information in this vital area, and Mr. DEVOLD suggested that the co-operation of countries working in this northern area might be sought with a view to collecting data relating to the occurrence of herrings, either by observing them near the surface of the sea, or by finding them in the stomachs of other fish.

A sub-committee, after considering this matter, formulated the following resolution: "It is recommended that Governments be contacted by I.C.E.S. in order to secure information on the occurrence of herrings in the North Atlantic, north of 58° N. and also in Arctic Seas. It is suggested that ships should be requested to transmit any information involving the following items:

(1) The position of herring shoals seen on the surface.
(2) Echo-sounding records of fish beneath the surface.
(3) The occurrence of herrings in the stomachs of other fish and whales."

Mr. ROYCE (U.S.A.) then outlined one of their problems concerning herrings. It was the occurrence of an epidemic disease which was capable of affecting up to 30 % of the herrings caught. The disease was caused by *Ichthyosporidium hofferi* and showed itself, in the early stages, as small black dots on the herrings. Epidemics occurred in a 16-year cycle and the effect was so great that Food Inspectors would not permit the packing of these fish during the outbreaks.

During a discussion of this subject, it was evident that this disease, or one similar to it, occurred in European waters but in proportions so small that it could be ignored.

The remainder of the meeting was devoted to a consideration of some of the national problems which had been submitted in writing by members.

A short summary of these problems has been prepared and circulated, but as the herring problems are so numerous, and so diverse, only a few of them could be tackled here.

The main divisions into which the problems were divided were these:

(1) Statistical Study of Herring Stocks.
(2) Fluctuations.
(3) Inter-relationship of stocks and migrations.
(4) Growth.

Mr. AGLEN (Scottish Home Department) opened the discussion on the question of stock changes and, referring to the recent discussions on herrings at the F.A.O. meeting at The Hague, he stressed the need for keeping a close watch for signs of over-fishing. New methods and devices were being introduced and it may be that stocks are not so invulnerable as one might suppose. Therefore the herring fishing countries should be on their guard and should be prepared to recommend protective measures should stocks become endangered. Dr. FINN (F.A.O.) supported this.

In the discussion which followed, evidence was given to show that certain herring stocks in the North Sea had undergone changes which were the result of fishing activities and the following recommendation was made:

"That, in view of the F.A.O. meeting at The Hague in August 1949, each country should take steps to keep a close watch for signs of stock changes and the possible causes of stock changes in the various herring fisheries. It is also recommended that steps be taken by every country to provide statistics of unit catches as well as of total catches (i. e., catches per unit of gear, and distinguishing where necessary between different classes of craft and gear)."

The time which remained was devoted to discussions on other national problems, such as the inter-relationship between stocks, the relationship between larvae and year-broods and the meaning of the first growth-zone on the scales.

The last session, on the morning of 1. October, was spent in discussing the three main recommendations, on tagging, on obtaining evidence of herring shoals in northern waters, and on stock changes.

W. C. HODGSON.

1.

Towards a Programme of Herring Research.

An address given to the thirty-seventh conference of the International Council for the Exploration of the Sea at Edinburgh, October 1949.

By

A. C. Hardy, D. Sc., F. R. S.

Linacre Professor of Zoology and Comparative Anatomy, Oxford.

When the International Council kindly honoured me by inviting me to give this address I hesitated before I accepted because I have been largely out of active herring investigations for some time now: not only for the years of the war but since, when I have been transferred to a professorship at Oxford where I have been very much occupied with other things and as far from the sea as I could be. During this time however I have remained as an Honorary Director of the work I began at Hull and my interest in problems relating to the herring has in no way diminished. Towards the end of the war I served on a committee to advise in the development of fisheries research in Great Britain when the war should end. At the request of this committee I drew up, with the help of Dr. Hodgson and Dr. Wood a scheme for a unified programme of research to bring together the work of the English and Scottish fishery departments, and that being undertaken by my old University department at Hull, to form one integrated attack on herring problems. It was, I imagine, because of this that you asked me to speak on the subject of herring research.

While I was diffident for these reasons, I was really glad to accept because I want to use this opportunity to express my belief that it is through herring investigations that marine science can, in the years immediately ahead of us, make its greatest contribution to the needs of the fisheries and at the same time make the most rapid progress in the development of fundamental oceanographical knowledge. Herring research is so many-sided; it embraces aspects of meteorology, physical and chemical hydrology, and plankton studies of all kinds in addition to the biology of the fish itself. It is because this field of work is so wide, that I believe, with the driving force of the economic urge to benefit the herring fisheries, more progress can be made in future oceanography, centred round this uniting and exciting theme, than can be made by any other means of attack. The advances that will have to be made, and are now well within sight of being made, must provide in turn a better knowledge of the sea from which to make further advances in investigating the more difficult and more indirect problems relating to the factors governing the lives of the bottom living trawl-caught fish. The herring being directly dependent upon the plankton, and the plankton upon its physical and chemical environment, we have here a chain of cause and effect which can be investigated link by link until the whole is complete. Much progress was made between the two wars; many of the links in the chain were established and we have ideas as to the way in which many others may be connected: ideas which can form the starting point of further investigations. When I say chain of cause and effect, of course I over-simplify it; it is really a series of many chains inter-linked at different points to form a great and complex ecological pattern. The more complete our knowledge of this pattern the more readily will we see its inter-connexions with the chains of cause and effect leading off and governing the lives of other fish. In short I want to plead for a programme of intensive herring research—including particularly plankton and hydrological research in relation to the herring fisheries—not simply for its economic end, which must be of great importance, but because I believe it can best produce the ecological structure round which all the rest of the ecology of our waters may eventually crystalize and fall into place.

In herring ecology we have some advantages in our methods of attack over those that can be used in investigating life on the sea bed. We are dealing with life in a fluid medium; we can sample the plankton and its physical environment at many points in both horizontal and vertical directions with our nets and water-bottles to give quantitative results which can be subjected to statistical treatment. And now we need not rely simply on the catches of the fishermen to give us our information as to the distribution and the extent of the herring shoals; a new instrument in the form of echo-sounding, as Dr. Hodgson is clearly showing us, is coming within our grasp to enable us to steam over an area and gain a knowledge of the frequency and size of the herring shoals within it. At the moment this work is in its infancy; who can

doubt that in the future it will give us results which will allow us to correlate the distribution of the herrings with their planktonic and physical environment[1]).

What I imagine you will wish me to do, is to give a sketch of the whole herring programme as I see it, not of course in any detail, but as a general view of all that I feel it entails, with perhaps some indication of the perspective into which the different parts might fall. I think this may be useful, not because I expect you will accept my views on the relative importance of this or that part of it, but because it will form a basis for discussion and for bringing together the many different aspects in relation to one another. I am putting up a programme to be knocked by discussion into better shape; something about which you can say "he's overemphasised this—he's completely overlooked that—surely his views on something else are very out-of-date—and so on". I fear that I may not be up-to-date in all the recent herring work that has been done.

Let me begin by suggesting the sort of questions which science should be able to answer if it is to help the fishing industry; then from this practical side we shall be able to see what necessary lines of investigation will be involved to enable us to supply the answers.

Research can assist the industry in two distinct and important ways: on the preservation side in helping to provide better means of dealing with the fish when caught, and on the biological side in enabling the fish to be caught more efficiently with reduced working costs while at the same time guarding against the dangers of over-fishing. It is with this biological—or oceanographical—side that we are here concerned.

The aim of this herring research should be to provide answers to such questions as the following which are all clearly of economic importance to the industry.

At one particular time, are herring more likely to be caught in this general area or that?

If the herring have not turned up on their usual grounds at their usual time, where are they?

Can science provide the individual boats working in a generally favourable area with a means of locating the shoals more easily from day to day?

What quality and condition of fish may be expected in a particular fishery?

Is this fishery likely to be heavier or lighter than usual?

Is the instrument of capture (drift-net, ring-net, trawl, etc.) the most suitable for this or that fishery?

If a drift-net is used, is it being fished at the most advantageous depth under the particular conditions prevailing for the time being? Are the fish perhaps on the grounds but not being caught because some unusual condition of the water (such as a temperature discontinuity layer) inhibits them from swimming up to the usual level of the nets?

Is the mesh employed the most suitable considering the future welfare of the stock (and so the future welfare of the industry)?

Is there over-fishing?

Are the herring trawl and drift-net fisheries attacking the same stock of fish?

Other important and unforeseen questions are likely to arise as research and a closer contact with the working of the industry are pursued. A constant liaison between the scientific workers and the practical fishermen is, I believe, as important for successful progress as is a close co-operation between the scientific workers themselves.

To stress the practical outcome of the work is not to suggest that research into the fundamental biology of the herring is of secondary and of only academic importance. Satisfactory answers to many of the above questions can only be given when we have a much fuller knowledge of the natural history of the fish in all its aspects, and this includes both the hydrological and planktonic factors in its environment. The pure biology of the fish can be the only secure basis on which to build the framework of an economic information service for the industry. Before we can forecast a deflection in the movements of the fish due to changing water, weather or planktonic conditions, we must have a knowledge of the more normal movements of the fish of different stocks. We must be able to distinguish the different stocks themselves.

The programme of work, as I see it, must keep these two aspects in view; fundamental research and practical help to the fishermen. In an ideal world in which there is no hurry it might be right to postpone all consideration of the second aspect until we had made very much more progress with the first. But the industry is in need of assistance *now*—and already science has gone some way in providing information of economic value: for example the forecasts of the quality and condition of fish, made by Dr. HODGSON at Lowestoft, the locating of large areas of unfavourable (phytoplankton) water and the provision of plankton indicating instruments to guide individual boats to better fishing in certain areas. Work on these lines should, I think, proceed concurrently with the more fundamental research, it being made clear to the industry that the information we can give may be crude at first, but will improve in reliability as the more fundamental work progresses. In this way, while caution must be excercised in preventing premature conclusions being passed to the industry, herring research can be of some assistance to the industry at once. This will not only help the fishermen but will help us. If they see from the beginning that we have their interests at heart they will be the more ready to co-operate with us and give much valuable information, which they alone can give, to help and guide us in planning lines of pure research. What they tell us in their own language must often be translated into somewhat different terms; while their

[1]) Since giving this address I have received news of the very recent, and not yet published, results of the Lowestoft workers in the Shields fishery; here they have obtained remarkable correlations between the distribution of herring shoals and the patches of their food Calanus.

conceptions may seem to us at times ridiculously unscientific, we must have sympathy with their ideas and ways of expressing them—for within the accounts of their experiences may often lie clues of great importance for the development of future work.

With this general introduction let me now set out the outline of the programme of herring research as I see it.

In the forefront I would place the work concerning the **stocks of herring and the age composition of the shoals.**

Clearly it is essential that we should have as full a knowledge as possible of the different stocks of herrings that make up the populations of our waters. Satisfactory forecasting of the ways in which abnormal hydrological and planktonic conditions may cause unusual movements of the herring must be based upon a previous knowledge of the more normal movements of the fish. The herring are clearly not a homogeneous population: there are distinct groups such as autumn and spring spawners perhaps in the same area; different areas may appear to have very different stocks of herring and evidence also indicates that some populations may make extensive seasonal migrations from one area to another. The charting of the main areas of distribution of the different populations must be given first place in the programme of fundamental research. The mixture of these different populations is a matter of some complexity, but already much progress has been made in distinguishing these different forms by workers in many different countries. We are having at this meeting important contributions on this subject such as those by your President, Dr. Andersson, dealing with the Swedish herring, by Dr. Jensen with Danish herring, and the work in this country by Dr. Hodgson and Dr. Wood.

From time to time the work on the so-called "races" of herring is attacked by those who rightly say that our present methods of investigation cannot reveal whether or not the differences we observe are truly "racial" ones in the strict biological sense of being races of different genetic constitution. It does in fact seem likely, if not certain, that some of these differences are ecological phenotypic modifications due to such environmental differences as those of temperature and salinity in the various regions in which they developed. Nevertheless it may be of considerable importance to know that there are these distinguishable ecological types turning up regularly in different areas because such types must have had distinctly different ecological histories. On the other hand it would seem most likely that many of the different forms, particularly those spawning at different times of the year, must indeed be genetically distinct. Here is a problem of great biological interest from an evolutionary point of view. Here we may be seeing incipient speciation taking place by different groups not isolated in space, but isolated in time: sub-species being formed not through spatial barriers preventing the flow of genes through the whole population, but by a similar prevention of gene flow between two groups in the population because for some reason their breeding seasons have become separated in time. Evolutionists of to-day tend to focus all their attention upon spatial isolation as the most important factor in the origin of sub-species and eventually of species, when isolation of gene flow in time may be a not insignificant factor.

The question of distinguishing true genetical races from ecologically modified groups is one of great importance. The investigation of the genetics of the herring might seem at first sight impossible: too difficult a task; but is not the herring problem so important to so many different nations that some effort might be made to start an institute for this purpose? Is it too fantastic an idea that we should have at one place on the seaboard of Europe a centre where the breeding of herring may be carried out? I visualise an establishment with a series of largish pools, perhaps connecting with the sea by lock gates, on the coast of some sheltered inlet. A series of such pools could be kept at different degrees of temperature and salinity. To this institute herring spawn would be sent by air from different parts of Europe—spawn obtained from known females of different races and fertilized with the sperm similarly obtained from known males. With careful work the technical difficulties of breeding such young fish beyond the yolk-sac stage to feed on cultured plankton could be overcome and they could be introduced step by step from smaller tanks to the larger pools. Here we could sort out the genetic and environmental influences and we should at last get the answer to many of our queries regarding the different races of herring. In place of the old fashioned sea-fish hatcheries, designed in the almost certainly vain hope of enriching the stocks in the sea, we should have a sea-fish genetical institute. By support from many different nations interested in herring problems surely one such breeding station could be financed on a scale to ensure success[1]).

Linked with the work on the stocks are the studies of the age composition of the different shoals which have already given us so much information. You are all familiar with the great achievements in this field: from the classical researches of Mr. Lea to the practical application by such work by Dr. Hodgson to which I have already referred. I would here just like to remind you of the notes of warning or caution that have from time to time been raised in this field and which must be kept in mind. There is the effect of the size of mesh used in the capture of the herring by drift-nets which may markedly influence the

[1]) When this was written and the lecture given I was unaware of Dr. A. Dannevig's recent promising results in rearing 105 individuals out of 500 herring larvae to a size large enough for the vertebrae to be counted. His Sea Fish Hatchery at Flødevigen, near Arendal, in Norway is just such an institution as I had in mind. (A. Dannevig: Rearing Experiments at the Flødevigen Seafish Hatchery 1943—1946, Journ. du Conseil, Vol. 15, pp. 277—283, 1948).

results of our estimates of the age composition of a shoal. Then there is the interesting observation made by Dr. Lucas who re-examined Dr. Fulton's published data on herring-trawl catches and demonstrated a diurnal variation in the proportion of larger herring in the catches; he showed that the proportion of larger fish was greater at night than in the daytime, suggesting a more extensive upward migration of smaller fish at night. He pointed out the possible effects of such a differential vertical migration upon the statistical estimates of age composition of the stocks: the proportions of younger and older fish in a sample may vary with the time of day or night. This, while demonstrated for trawl-caught fish from the bottom, must apply equally for the drift-net fish caught at the top and is clearly a point which should receive further attention.

Migrations.

Next in importance to the correct recognition of the distinct stocks of herring must surely come the working out of the normal migrations of these different races. For years the problem of successfully marking herring has baffled us. The metal tagging and extracting of marks by electro-magnets which has been so successful in the North Pacific fisheries is only applicable in our waters where the fish are dealt with (as in America) in a canning or a fish-meal works and so, for us, is very limited in its application. All at once the picture has changed; new experiments are being made which promise us great success. Dr. Wood, here in Scotland, has devised a new form of marking band and has already had a few recoveries, and now I have only just heard, a few hours before this lecture, of the remarkable results of Dr. Höglund's Swedish tagging experiments using Mr. Lea's new hydrostatic marks. In these latter experiments, out of 525 herring marked, already 15 have been recovered some of which have been recaught after as long a period as 164 days; six were recaptured within 10 miles of the point of liberation and the other nine at distances from 35 to 340 miles. Particularly interesting was the capture of two Swedish herring on the Fladen Ground; this offers a proof of the conclusion come to on other grounds by your President, Dr. Andersson, that the autumn-spawning herring of the Fladen Bank and the winter herring of the eastern Skagerak are of one and the same stock. This, I think you will agree, marks a turning point in the history of herring research; at last a method of working out migrations and linking the herring of different areas is coming into our hands; one of the greatest difficulties of all herring research has been removed. Any future programme must certainly give a prominent place to investigating the regular movement of the different stocks.

Spawning Grounds and Distribution of Larvae.

Next perhaps I should refer to the work of charting the various spawning grounds and the distribution of larval and post-larval stages. It is of course unnecessary to emphasize the importance of this work and already much has been accomplished, but still much more work needs to be done. In this field there is a vast amount of information which we all hope is soon to come to us. For years Dr. Clark has made a great study of the distribution of young herring in Scottish and adjacent waters; he holds vast stores of results and I am sure we all hope that in his retirement he may before long give birth to this important child of his.

In passing I should just like to mention the interesting experiments being made by Dr. Wood in which he is laying down series of plates, linked together by connecting lines, across areas thought to be spawning grounds, so as to investigate the deposition of the spawn. Not only must our future programme include more work on the distribution of young herring but on the survival rates of different broods in relation to planktonic and hydrological conditions.

Hydrology.

It is again quite redundant to stress the importance of hydrology for our work in throwing light both on the normal or abnormal movements of the shoals and on the drift of the larvae. We must have the closest co-operation with the hydrologists, discuss our problems with them and persuade them to design cruises to furnish us with the sort of information that we want. The influence of currents and their variation on the herring stocks must be profound. I need only mention one example as an illustration: the investigations being developed by Dr. Carruthers and Dr. Hodgson just before the war, which suggested a relation between the flow of water to and from the English Channel and the survival of herring broods in the southern North Sea. Equally important of course is the study of the variation in the inflow of water into the northern North Sea or indeed to or from any area in which young herring regularly develop.

Meteorology.

Apart from the indirect effect of the weather on the herring, as for example the possible effect of varying sunlight on the development of the plankton, particularly phytoplankton, we have some interesting suggestions regarding direct effects. By a statistical system of plotting the positions and weight of the catches of individual boats comprising the fleets in different fisheries, Dr. Hodgson has been able to study the changing shape of shoal concentrations in relation to wind direction with very promising results. Mr. Ford also made interesting observations on the effects of periods of storm on the Plymouth fisheries; possible similar effects should be looked for in other regions.

The Moon.

A note might be made, for future consideration, of a possible investigation into the influence, if any, of the moon on shoaling in fisheries other than East

Anglia. While the striking relation between the autumn herring landings at Yarmouth or Lowestoft and the phases of the moon is now firmly established, no similar relation has been shown elsewhere; in fact just the opposite appears to hold good for the west of Scotland. It may be that fish preparing to spawn always shoal together more at the full moon, but in the clearer Scottish waters the drift-nets may be more visible to the herring in bright moonlight than in the thick East Anglian waters and so the landings on moonlight nights in Scotland may be less. Dr. Wood, however, tells me that the ring-net catches on the west of Scotland are also adversely affected by bright moonlight.

Plankton.

Work on the plankton in relation to the herring has been my special interest. It was at Lowestoft in 1922 that Mr. Savage and I began our investigations on the effect of phytoplankton on the herring; it was there too that I began the initial experiments with the little plankton indicator to try to correlate the catches of herring with the conditions of the plankton: work that we developed later at Hull to a much greater extent.

Since the herring is directly dependent upon the plankton for its food, both in adult and post-larval life, a study of the plankton in relation to the fisheries must form a part of any comprehensive programme of herring research.

Further it is necessary to have a broad picture of the changing plankton population over the whole area from month to month—or sometimes even from week to week—for several reasons. We want to have information about the major areas of phytoplankton concentrations, which appear according to so much evidence to be avoided by the herring, and likewise information of areas of abundant herring food, particularly Calanus in the northern North Sea and Temora in the south. Then we want a knowledge of the general plankton situation in relation to the survival of different broods of young, for example the relative abundance in different years of Pseudocalanus which is so important as a food for the young post-larval stages. Further such a survey over a wide area can give important information as to the movement of those particular plankton organisms which can be used as indicators of different types of water and so supply evidence, supplementary to hydrology, of the changes in the principal water movements, such, for example, as the fluctuations in the Atlantic inflow into the North Sea.

It was to provide information as to the changing conditions in this background of the plankton that we began the regular monthly survey from Hull using automatic sampling machines—the continuous plankton recorders—towed by steamships travelling on regular commercial routes. We began at first in the southern North Sea with lines from Hull to Bremen, to the Skagerak and to Rotterdam, and later a line from London to Esbjerg; then, opening a laboratory at Leith (Edinburgh), we ran lines from here to the Skagerak, to Hamburg and to the Shetlands and lines from the Pentland Firth to Bergen and to Iceland. After closing down for the war we have now restarted and are expanding the survey further into the Atlantic by lines from Glasgow to the two British weather-ships and with the kind co-operation of Norway running a line north to their weather-ship in the Arctic.

From these intercrossing lines of observation repeated month by month we can see the moving boundaries of distribution of various organisms such as Tomopteris, *Sagitta elegans*, the pteropods *Clione limacina* and *Limacina retroversa*, etc., as they advance round the north of Scotland and pass down the western side of the North Sea with the Atlantic inflow. I must apologise for referring to our plankton recorder work first; I do so because I believe it is the instrument to give this broad background of planktonic changes over a wide area. A study of these broad changing planktonic conditions can only be carried out as is the study of the changing conditions of the weather by having a number of observations taken at the same time over a very large area. One research ship cannot do this; it can only be done by a fleet of ships—and for this we must seek the kind assistance of a number of different steamship lines. We owe a deep debt of gratitude to the many shipping companies and their officers who have given and are giving us such valuable help.

No less important are the plankton investigations calling for a special research ship and the use of the horizontal and vertical tow-net. There are such problems as those Mr. Wimpenny and Mr. Cushing are specially working at at Lowestoft: the relation of the fat content of the zooplankton to the condition of the herring, and on the ecology of diatom patches, their growth and development. Then there are such problems as Mr. Fraser of Aberdeen is particularly interested in: the relations of the plankton, both food and predatory organisms, to the brood survival of young fish and on the influence of such predators as Ctenophores and Medusae in reducing the supply of planktonic food of adult fish. An ecological study of Calanus production and its *destruction* is badly needed. I shall later refer to recent Russian work in this connexion.

It may seem to some that the problems of the plankton and its relation to the herring are too vast to be brought to any satisfactory and practical conclusion. I do not share this view; I believe that all the different pieces of work that are now progressing are coming nearer and nearer to the point when they will begin fitting together like the pieces of a jig-saw puzzle.

What proof have we that our methods are really adequate for the solution of our problems? I would like to describe two personal experiences of plankton work which give me the confidence I have just expressed. They are the same two examples that I used in my recent address to the Zoological Section

of the British Association for the Advancement of Science to illustrate the validity of ecological methods in general, but they have a closer significance here. I may seem to be giving a disproportionate amount of time to this, but I do so because I want to show on what grounds I base this confidence in the kind of plankton work which I feel should take an important place in any future programme of herring research on a broad scale.

The first example concerns the plankton in relation to whales instead of herring but the principles are just the same; it comes too from the other end of the world, from South Georgia in the Southern Ocean where in 1926 and 1927 the old R.R.S. "Discovery" and the smaller R.S.S "William Scoresby" together carried out an intensive survey of the plankton and hydrology round that island. My friend the late Mr. Rolfe Gunther, so tragically killed in the early days of the war, worked with me on the plankton and together we published the results. South Georgia, a long narrow mountainous island about a hundred miles in length, lies some 900 miles due east of Cape Horn; it lies diagonally across the path of the westerly drift of the Southern Ocean at a point where water from the Bellingshausen Sea (in the extreme south of the Pacific Ocean) meets with water flowing out of the Weddell Sea, that great ice-covered gulf bitten out of the Antarctic continent. Here is one of the places where the largest rorquals, the blue and fin whales, congregate in summer to feed upon the vast shoals of krill—the prawn-like Euphausiaceans (*Euphausia superba*)—which inhabit these seas in such amazing numbers. I must try to condence a long story into a few words. We surveyed the waters round South Georgia by a series of radiating lines running out from the coast to beyond the continental shelf; the two ships took part together, working different parts of the survey at the same time, stopping every 15 miles to take samples and observations. At each such station standard methods were used: large coarse-mesh nets to catch the krill and small very fine-mesh nets to catch the microscopic plants—the phytoplankton—and, of course, the sampling of the sea water for analysis. Before the design of the survey repeated hauls with the plankton nets were made in series to test the patchiness of the more important forms and so determine the length of tow necessary at each station to give a reasonably valid result. At the same time as the survey was undertaken all the captains of the whale-catchers operating in the district were asked to record the positions of the different whales they killed. We were thus able, at the end of the survey, to prepare a series of contour charts showing the varying distribution of the different items sampled: the whales, the krill, the phytoplankton the temperature and the various chemical characters of the water such as salinity, phosphates and nitrates, the oxygen content and its alkalinity (in terms of hydrogen-ion concentration). The distribution of the whales was correlated to a remarkable degree with that of their food, the krill; the same thing had been found in an earlier survey the year before when the krill was much more concentrated against the coast, as also were the whales. Now the distribution of the krill in the main survey and that of the phytoplankton were inversely correlated; where the krill were abundant the phytoplankton was scarce and *vice versa*. Whether the phytoplankton was scarce were the krill was because the krill had grazed it down or whether the krill was excluded from the zones of dense phytoplankton, according to a hypothesis I put forward, does not matter for the present argument. (This is the subject of a renewed investigation at the present time). Further the contoured maps of phosphate values gave a remarkably close inverse correlation with the phytoplankton distribution: where the little plants were more abundant, the phosphates in the water were more used up. The alkalinity (pH) contours also gave a good correlation: the water being more alkaline in the regions of dense plant production because of the carbon assimilation.

From the phosphate chart we could deduce the phytoplankton distribution; from the phytoplankton chart we could in turn deduce the distribution of the krill, and finally from that of the krill we could deduce the distribution of the whales. If this state of affairs was a usual one, then it seemed likely that we could predict the distribution of the whales direct from a knowledge of the phosphate values. One would expect whale concentrations only in regions where the phosphate values were relatively high. High phosphates mean poor phytoplankton, poor phytoplankton means rich krill, and rich krill means many whales. Such a chain of inference is of no commercial significance in this particular case, for if one set out to chart the phosphate values to predict the whale distribution one would see the whales themselves blowing, if one kept one's eyes open, long before one could work out all the phosphate values and chart them. If however we can repeatedly show that the whale distribution is correlated with the phosphate distribution, then we will know that in our ecological methods we are getting to grips with reality in nature. After we returned from the 1925—27 expedition on the old "Discovery" and I had left to become a professor at Hull, the new R.R.S. "Discovery II", or sometimes the little "William Scoresby", again visited the South Georgia whaling grounds in several seasons to survey the plankton and hydrological conditions, and as before the whalers kept records of the position of the whales they killed. I should explain that the number of whales killed during most months of the season usually runs into many hundreds and so their pattern of distribution can be contoured like that of the plankton and phosphates. The plankton had not yet been worked out, but the phosphate values were soon determined and published. Charting these phosphate results for three further seasons one was able to say that from the correlations obtaining in the 1926 survey one would expect to find the whales in some areas and not in others. In each case the inference was correct. It

was a pleasant experience for an ecologist sitting in a room at Hull to be able to work out correctly the main features of the distribution of whales at the other end of the world from a table of phosphate values. The exciting climax came when I considered the conditions at South Georgia in the season of 1928. In that year the "William Scoresby" had made a survey of the plankton but had not taken phosphate measurements. In this season the whale distribution turned out to be most exceptional, quite at the opposite side of the island to the more usual positions of concentration. The plankton had not yet been worked out but was stored in bottles in the British Museum. From the whale distribution I now forecast in broad outline what the plankton distribution should be like when it came to be worked out and asked Dr. KEMP if he would have it examined. He did and the distribution was just as expected[1]). As nothing else can do, prediction gives confidence in ecological method.

Confirmatory evidence from the results of two entirely independent workers also assures us that our methods are sufficiently adequate to give solutions at any rate to some of our problems. My second example is of this kind. In the summers of 1931, 1932 and 1933 we at Hull were making trials with our small instrument, the plankton indicator, which was being used from herring drifters to collect samples of the plankton at the places where they fished. We were working out correlations between the catches of herring and the state of the plankton. The little hollow torpedo-shaped indicator was towed for a mile by each drifter just before the nets were put out for the night's fishing and the sample of plankton was obtained on a gauze disc which could be taken out of the indicator after use. These samples were then wrapped up and preserved in a formalin container and returned to us with a label giving the date, position and number of herring caught in the nets. In addition to the Scottish fisheries we were making an intensive study of the Shields fishery, off the Tyne. Quite independently at the same time Mr. SAVAGE of the Ministry of Fisheries Laboratory at Lowestoft was working on the food of the herring and obtaining preserved herring stomachs from this same Shields fishery for analysis of their contents. In the late summer of 1931 the positive correlations, which we had been finding at other times and places, between the numbers of herring caught and the quantities of their favourite food in the plankton—the copepod Calanus—failed. The Calanus at this time had become exceedingly scarce and the herring were now feeding, as Mr. SAVAGE showed, largely upon Sagitta and the pteropod Limacina. By comparing our results with those of Mr. SAVAGE it was found that the average quantities of these two organisms upon our plankton indicator discs for a complete series of seven 10-day periods during July, August and September, bore an extraordinarily close relation to the average number of these organisms found by Mr. SAVAGE in his herring stomachs. The two curves for each organism rose and fell together with an almost unbelievable correlation[1]). In the summer of 1932 and 1933 the herring were feeding largely on Calanus and it was abundant in the plankton. There was now a good correlation between the Calanus on the indicator discs and in the herring stomachs as found by Mr. SAVAGE; but no such correlation in the case of Sagitta and Limacina. During these two summers also the correlations between the numbers of herring caught and the distribution of the Calanus in the plankton were markedly positive.

Confirmation and prediction show that planktology is advancing to the point where it can give valid answers to the questions before it. To achieve this we must be sure that our plankton collecting gear is really giving us an adequate sample, particularly in relation to the patchiness of the plankton; we must obtain statistical evidence of its reliability. Before beginning any survey in a new field we must carry out trials, like the controls of an experiment in the laboratory, to test our methods; by repeating our hauls at short distances apart, or in the same place at short intervals of time, we can see to what extent we can repeatedly get similar results. Dr. BARNES at the Millport Laboratory is now carrying out important statistical studies on the validity of plankton-collecting gear.

I must now say a little more about the direct correlation of the state of the plankton and the catches of the herring fishermen. I have just referred to the work we did at Hull with the small plankton indicator, working in both the Scottish and English fisheries from 1930—1933. I have outlined the methods employed and I need not go into them further; they are fully described in the *Journal of the Marine Biological Association* Vol. XXI, pp. 147—291, (1936). You may remember that we dealt with the results we obtained according to different areas defined by degrees of latitude and in half-monthly periods. For each of the area-periods we worked out correlations between the quantities of Calanus present on the indicator discs and the catches of herring taken at the same time. They showed that more often than not larger catches of herring were made in water having a larger number of Calanus. For each area-period we arranged our samples of Calanus in ascending order of quantity—we then separated the samples into two batches: the half with the lower Calanus values and the half with the higher. We compared the total of the corresponding herring catches in the two halves and found that the catch of herring was higher in the richer Calanus water in 30 out of 40 such half-monthly area periods. For each half-monthly period we worked out a theoretical gain or loss that the drifters might have experienced if they had fished entirely in the waters which were richer in Calanus and found for the Scottish fisheries—taking

[1]) Discovery Reports, Vol. XI, pp. 276—301, 1935.

[1]) Hull Bulletins of Marine Ecology, Vol. I, p. 252, 1941.

the losses with the gains—that the average result on the whole series of periods gave a gain of $24{\cdot}5 \pm 7{\cdot}7\%$. In the Shields fishery a similar calculation gave an average gain of $12{\cdot}7 \pm 6{\cdot}7\%$ for the whole series—or by omitting the incompletely sampled and abnormal year of 1931 (already referred to) the average gain is $21{\cdot}2 \pm 7{\cdot}5\%$. In addition to the positive Calanus correlations marked negative correlations with phytoplankton were obtained.

Since the war this work has been taken up again by the Hull department, only this time working more intensively in one fishery: at Fraserborough. Working here for the last three summers, using a somewhat smaller indicator but getting many more boats to use them, we have been able to get sufficient results to give us daily correlation tables instead of half-monthly ones. There is a general confirmation of the previous results, but a lot of new information is emerging. I was at first hoping to give you some account of this but it would take too long and need too complicated an explanation to fit into this general lecture; also the results are not yet fully worked out; Dr. HENDERSON and Mr. GLOVER are still engaged on them. Perhaps at next year's International Council Meeting a full account of it may be given to you; I am confident that this work is going to throw some valuable new light on the ecological relations between the plankton and the herring.

A striking confirmation of our positive correlations with Calanus has been obtained by Dr. Á. FRIÐRIKSSON using our plankton indicators in the Icelandic herring fisheries.

The Russian oceanographers have carried out extensive work on the plankton of the Barents Sea from 1931 to 1939 and particularly in relation to the herring fisheries in 1938—39. A number of papers have appeared but the greater part of the work has been brought together in the large paper by B. P. MANTEUFEL in the *Transactions of the Knipovich Polar Scientific Institute of Sea Fisheries and Oceanography*, Vol. 7, published in 1941. The Hull department has now had a translation of this made and it is clearly a most important work. At times they have had several research vessels working in the area as well as a large number of fishing vessels equipped with plankton indicators or Hensen nets. As few marine biologists outside Russia appear yet to have seen this paper, or a translation of it, I think it will be useful if I quote from the section on "General Conclusions and practical indications for finding the herring". Here and there I will add a few comments.

"There is not only" he writes "a dependence between the herring and the plankton in relation to food, but there is also an important negative influence upon the shoaling of herring of mass-development of phytoplankton: and finally there is also an indirect connection between the plankton and the herring due to the changes in the surrounding water (temperature, salinity).

"The period from May to July is the time when the condition of plankton has a direct and strong influence upon the biology of herring. From August this direct influence of the plankton upon the herring begins to disappear. At that time the hydrological factors begin to determine the behaviour of the herring. Therefore, from August and onwards the problem of ecological indicators is of great importance. In winter the distribution of the herring depends very little upon the plankton.

"We consider the method of comparing the herring with a definite complex of plankton ('weedy', red Calanus, etc.) as the most expedient one. This method has been adopted in this paper. First of all, such a method allows one to come close to the problem of the antecedents of phenomena, and, secondly, it is the most convenient method for fishing. Each skipper can easily determine the complex of plankton for these complexes are usually very clear. The indexes that Hardy used for water, 'richer' and 'poorer' in zooplankton, having an extremely relative character, are not convenient for practical use."

(I think he has not understood the use of our terms 'richer' and 'poorer'; they were not intended for 'practical use'.)

"Our investigations shed light upon the correlations between the shoaling of herring and the different complexes of plankton. This is of particular importance in May and June, i. e. during the period when the shoals of herring are moving quickly and are difficult to find. During these months the herring can be successfully found only on condition that all the fishing boats are armed with apparatus for collecting plankton (plankton indicator, HENSEN's nets). It is necessary to collect together in good time the data obtained and to give operative scientific advice to the herring fleet. An experiment of giving such advice was very successfully fulfilled in May 1939 when a detailed survey of hydrology and of plankton was made by the crew of s.s. 'Persey' in the south western part of the Barents Sea. This survey, supplemented by data obtained from fishing drifters gave a clear picture of distribution of plankton, and thus constant advice could be given to the reconnoitring fleet. Helped by this information, the herring fleet found several large shoals of herring and fished them successfully. However, as at that time some of the laws[1]) were not sufficiently studied and as the drifters did not always use the advice received, a large number of drifts were made in zones of plankton unfavourable for the shoaling of herring . . .

"The practical instructions for reconnoitring herring, resulting from the present work, can be thus summarised.

1. Strongly 'weedy water' acts negatively upon the shoaling of herring. Therefore, in May and June slimy, bright green and brown-green discs of indicators of plankton as well as green mist in samples collected with HENSEN's nets for plankton, with a rather sharp smell, characterise waters unfavourable at the given moment for the fishing of herring. If it is necessary to fish herring in these waters, one has to use drifting nets on long ropes below the zone of algae. In such regions the presence of herring jumping over the surface of the water does not indicate the presence of commercial shoals of herring. In July discs and samples of plankton also indicate 'weedy' (summer 'weedy') which is unfavourable for herring.

2. In May and June the shoaling of herring takes place near the boundaries of the shrinking zone of 'weedy' water, often with some remains of algae which stain the discs of the indicators of plankton into yellowish-green

[1]) Against the word 'laws' the translator adds this note: "probably laws governing the movements of the herring, plankton, etc", but I think it really means instructions issued to the fishermen regarding the plan of campaign.

shades. This shows that the conditions are favourable for the shoaling of herring. When the boundaries of the region of 'weedy' water have been found, the drifts must be made in the direction (?)[1]) of the south-western quarter from this boundary. The presence of small numbers of herring within the regions of the boundaries of 'weedy' water often indicates the presence of large shoals of herring 5—10 miles westwards or south westwards (against the current).

3. In July, the zone of 'weedy water' coming from the west moves behind the shoals of herring, therefore one has to look for herring east of the boundary of this migrating zone.

4. In May and June the zone of red Calanus is not favourable for fishing herring for though large numbers of herring feed in this zone, they do not form shoals. During these months, on getting a red disc of the plankton indicator one must move in the direction of the north-western quarter: where beyond the boundaries of the moving zone of the red Calanus one has a good chance of finding shoals of herring. The pink colouring of the discs, due to the presence of young Calanus, is somewhat more favourable for fishing than the red colouring. Catches in these zones occasionally reach over 10—20 kgs. per net, per drift. In July the herring shoals in the feeding regions: therefore shoals of herring at that time can be often found in the zones of the red Calanus with a bright red colouring of the disc."

In the body of the paper he deals extensively with these interesting relations between the occurrence of the red Calanus and the herring catches. The red Calanus indication on the disc is only of direct value during the first half of July—and then it is said to be extremely effective. During this time, the herring which have formerly been in small shoals, now unite to form large shoals feeding intensively on the Calanus. At this time enormous quantities of Ctenophores also appear in the plankton; he shows in the paper how these must play an important part—with the herring—in grazing down the Calanus which towards the end of July is so reduced in numbers that it no longer serves as an indication of herring. In the Barents Sea there is apparently only this one brood of Calanus in the year, which makes conditions in this fishery very different to those in most other areas.

Now to resume his summary:

"5. In July—September the herring is found to a large extent in waters with a rather poor plankton. Marked diminution in quantity of plankton (occasionally found in patches) often indicates the presence of large shoals of herring.

"6. In the second half of July and later on, Ctenophora and small thermophile summer crustaceans (Copepoda and Cladocera) often indicate waters favourable for the shoaling of herring in the open sea.

"Further investigations of this problem by methods of comparison and experiment will improve our knowledge and give further direct indications of the possibilities of using the plankton as an indicator of places for the shoaling of herring or places where herring is absent.

"The practical significance and the theoretical difficulty of such investigations show the necessity of similar investigations in the other seas of the Soviet Union in relation to a number of other pelagic fishes feeding upon the plankton."

[1]) Translator's note: The Russian text is not clear.

These two final paragraphs of MANTEUFEL's paper which I have just quoted I may use, with the substitution of the words "seas of the International Council", to express my own reason for devoting so much of this address to the inter-relations between the plankton and the herring. Ever since I gave to my first paper in herring research, in 1924, the title of "The Herring in relation to its animate environment" I have felt that such ecological work is the key to a more efficient exploitation of the herring fisheries.

Next in importance in the herring programme to the work on the nature of the stocks themselves and their migration, I would place the study of these ecological relations between the plankton and the fish.

I have now left myself time only to give the briefest reference to other items which should be included in a comprehensive programme.

"White Water".

One frequently hears herring fishermen talking of 'white water' or 'milky water' as an almost infallible sign of good fishing if they can find it. It does not appear to be a common occurrence, but when it is present many (but not all) will say they are sure to get a good catch. For years I have heard of it, but I have never seen it and know of no scientific account of it or its cause. Some investigations into this in Scottish waters are now in hand and the Russians have some interesting observations on it in their waters.

Food and Feeding Habits.

So much work has already been done on the food and feeding of the herring, particularly by Dr. JESPERSEN and Mr. SAVAGE, that perhaps little more is required at present except in special areas and in relation to particular problems.

Fishing Gear.

Consideration of possible improvements in fishing gear should certainly have a place in the general programme of research concerned with the catching side of the industry. How far the biologists should be concerned with this may be a matter for discussion; but in some aspects, as in the question of mesh size in relation to over-fishing they are clearly involved. Either by biologists or others, experiments should be made with drift-nets fished at different depths at the same time to determine whether the traditional practice in regard to depth of net is in fact the most efficient for a particular fishery. I was told on the Moray Firth that it is the practice of many Scottish fishermen to reduce the depth of the net as the summer season advances. Is such a reduction advantageous in every season? Should it be postponed in some years or accelerated in others? Perhaps it might be arranged for a few drifters always to use a series of nets at varying depth to act as pilot vessels indi-

cating from time to time the most advantageous depth at which the whole fleet should work.

Then the relative merits of the drift-net and the ring-net should be compared in different fisheries. It is likely that a considerable increase in the use of the ring-net in more open waters will be attempted; but many doubt if it can be used so well in the heavier weather conditions of the open sea.

The investigation of the selective action of different nets is obviously important.

Over-Fishing.

For some time now Dr. HODGSON and Dr. WOOD have thought, though for different reasons, that there are signs of over-fishing of the herring. They both agree that there has been a shortage of larger older fish since the middle twenties as compared with former times; but they disagree as to its cause. The one regards this as due to the adoption by the industry of a smaller mesh, which not only yields a larger proportion of small fish (and so smaller proportion of large fish) in the catch, but killing off many of the immature fish leads, he thinks, to real over-fishing and an actual reduction in the number of older fish. The other considers that the great development of herring trawling, largely by the Germans, on the Fladen Grounds since the last war has resulted in a heavier destruction of the older fish since the younger ones, he believes, do not congregate in this deeper water to anything like the same extent. This divergence of view is all to the good if, as they hope, they can work together in finding the correct solution; the investigation of each view will lead to important conclusions other than the actual point at issue. On the one hand the whole question of the size of mesh used and the resulting size of fish caught is one of economic importance and on the other the question as to whether the fish being trawled on the Fladen Grounds are of the same stock as those taken in the drift-net fisheries (and in which of them) is an essential step in the sorting out of the different populations. Now at this meeting Dr. HAVINGA has given us in his paper unmistakable evidence of over-fishing in the herring fishery off the Netherlands. We are at last brought to realise that our stocks of herring are not an inexhaustible supply as so many in the past have tried to make us believe.

Fish Behaviour.

Last, but not least, the study of animal behaviour must play its part in our programme and work included on the shoaling behaviour of the fish: for example investigations to follow up the very interesting suggestions of mass excitement in spawning shoals put forward by Mr. MICHAEL GRAHAM (Journ. du Conseil, Vol. VI, p. 252, 1931).

It has been impossible to cover all the ground that I would like to in trying to present a balanced picture of all the different aspects of the great adventure in herring research. But I am sure we all realize what a huge problem it is.

I would now like to end by throwing out a suggestion —only a suggestion—to start a discussion. It concerns the scale on which we should work. It seems to me possible that there are problems which are so big that they cannot be satisfactorily solved unless they are attacked upon a sufficiently large scale. I should imagine for instance that there are many problems which could never be solved, not even in a million years—if we could only work for say 10 days a year at them, but might easily be solved in ten years if we worked all the time at them. What I am leading up to is this: is it possible that the sea is such a big and complicated place, that, because research resources must be limited, progress in research may be much less in the long run if we devote ourselves to a number of different problems at the same time instead of taking them in turn one at a time? In other words would it be better for us to devote all our resources and energy to herring research first and not at the same time also attempt research on cod, haddock, plaice, etc? I believe that if all the nations who are at all interested in the herring were to put herring research first we should make the greatest progress— not only in herring research, but in the long run to the other lines of work because these other lines would link on to the extensive ecological framework we should have established in relation to the herring.

In Great Britain we are achieving a much closer co-operation between the herring research workers in the two fishery departments of England and Scotland than we have ever had before; a special herring research vessel is now shared between the two. Their problems are the same and their fields of interest overlap. As your President has shown us, the east Swedish and the Fladen herring are the same stock; so will it be found that there is common ground between the herring work of all the various nations. I hope in time we may come to see the scientists of different countries joining together in cruises on the same research ship to solve together their common problems and together writing joint papers on their results.

Conferences such as the one we are now attending, where we can meet and exchange our views in such a friendly atmosphere, should lead towards a closer and closer co-operation between us and must hasten the solution of the many problems centering round the biology of *Clupea harengus*: the fish which has played such an important part in the history of many nations and must always be a prominent feature in the larders of the western world.

2.

Contributions to the Study of Fluctuations in a Fish Stock.

By

Finn Devold

At the end of the last century ichtyologists became more and more interested in age determinations of fish. In 1903 the Norwegian zoologist Dr. Broch (1908) discovered that the scale of the herring could be very conveniently used for age determination. The late Professor Johan Hjort and Professor Knut Dahl were very interested in this matter, and regular collecting of herring samples for this purpose started in Norway in 1907. In 1909 Mr. Einar Lea took charge of the herring investigations, and he continued and extended the collection of samples, so that we now have uninterrupted records of the age-composition in the tribe of Norwegian herring for the last 42 years.

Professor Hjort and Mr. Lea were very interested in calculating the fluctuations of the stock; and when samples had been collected over a series of years, Mr. Lea worked out a method for calculating the mortality and fluctuations, a method which is described in his paper "Mortality in the Tribe of Norwegian Herring" (Lea, 1930).

Figure 1 demonstrates the calculated fluctuations in the stock from 1907 until 1949. It also shows the output of the winter herring fisheries over the same period. Broadly speaking, the calculated stock has steadily increased during this period, and at the same time the output of the fisheries has also been steadily increasing.

As far as I know, no objections to Lea's formula have been published, and we have felt very safe every year when presenting prognosis of the herring stock for the coming year's fishery, based on such calculations.

In the last 2 years the present author has been responsible for these forecasts and has therefore felt it necessary to examine the reliability of our calculations. According to Lea, it is possible to calculate not the real number of herring, but the proportion of the increase or decrease, taking the stock in one of the years as unity.

Mr. Lea has chosen the year 1907 as unity, and from Figure 1 we see that the calculated stock has grown

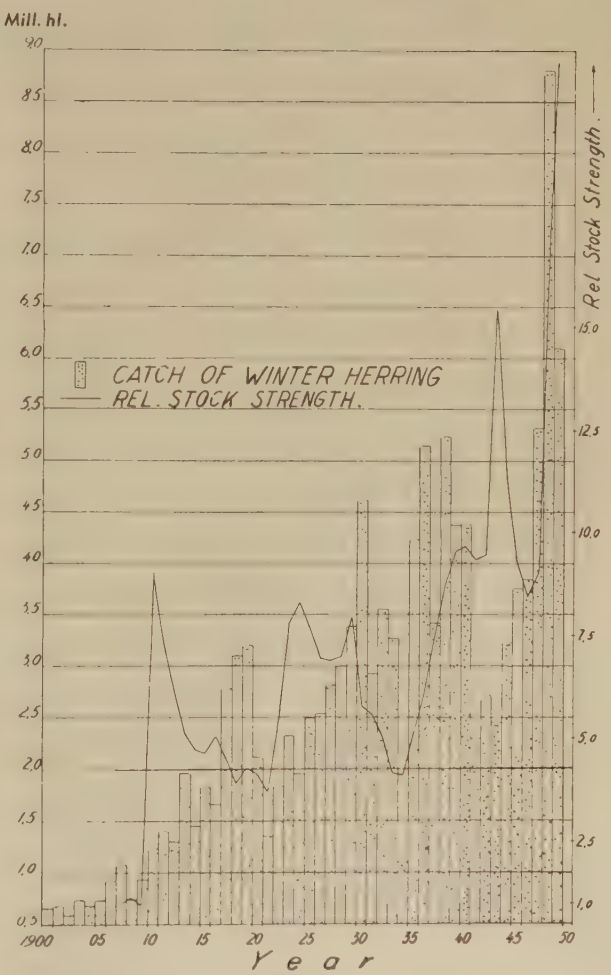

Fig. 1. The calculated fluctuations in "The Tribe of the Norwegian Herring", and the total landings of winter herring in Norway the respective years.

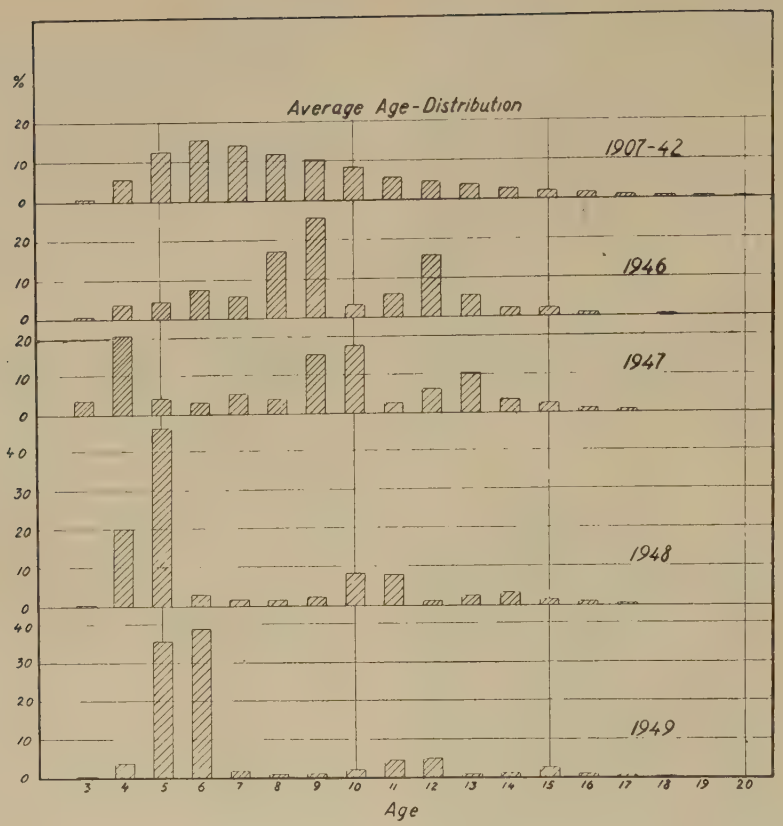

Fig. 2. The average age distribution in "The Tribe of the Norwegian Herring" in the years 1907—1942, and in the last five years.

to about 17 in 1948, and if we calculate the year 1949, we find that the stock is 21·5 times the size of the 1907 stock. The tribe of the Norwegian herring contains without doubt milliards of herring. At the same time, a very simple calculation gives us the result that 100 herring fishermen, operating with purse seines, are killing during a season as many herring as 20.000 fishermen in the Lofoten area are killing cod.

During the last 3 years the herring fisheries have been expanded to such a degree that the annual landings have increased to about 3 times the average catch 1907—1942, and it is very important to determine if this expanded fishery has diminished the stock.

The application of Lea's formula demonstrates definitely that it has not.

Table 1 and Figure 2 show the age distribution of the Norwegian spring herring stock in recent years. In Figure 2 the first columns demonstrate the average age distribution from the year 1907 to 1942. The following columns give the age distribution for the respective years. It seems as if 2 very strong year-classes, born in 1943 and 1944, have entered the Norwegian tribe of herring. These 2 year-classes in 1948 constituted about 67% of the entire spawning stock, and in 1949 they constitute about 75%.

It is easy to calculate that each of these 2 year-classes is about the same size as the famous 1904 year-class, which according to Lea's calculations, was able alone to make the total tribe of the mature Norwegian herring more than 9 times as numerous as it had been before this year-class entered the spawning stock. But we will examine his formula and see if such calculations are reliable.

Instead of using the unknown number of the enormous herring stock, we will build up a theoretical stock

Table 1. Age Distribution in the Norwegian Spring Herring.

	Age							
Year	3	4	5	6	7	8	9	10
1946.....	0·5	3·7	4·4	7.4	5·6	17·2	25·8	3·2
1947.....	3·7	20.5	4·3	3·1	5·3	3·9	15·3	17·6
1948.....	0·2	20·1	46·5	2·9	1·6	1·5	2·2	8·2
1949.....	0·2	3·9	35·6	39·0	1·7	0·9	1·1	2·1

	Age							
Year	11	12	13	14	15	16	17	18
1946.....	5·9	15·9	5·4	2·1	2·1	0·7	—	0·2
1947.....	2·6	6·2	10·3	3·4	2·4	1·0	0·6	—
1948.....	7·9	1·0	2·4	3·1	1·4	0·8	0·2	—
1949.....	4·6	5·0	0·9	1·2	2·6	0·7	0·5	0·2

Table 2.

Stock $\varsigma = 0.80$		Age Distribution ‰	
Example 1.			
$A_3 + A_4 + A_5 + A_6$	= 1000	$a_3 + a_4 + a_5 + a_6$	= 183
A_7	= 1000	a_7	= 183
A_8	= 800	a_8	= 146
A_9	= 640	a_9	= 118
A_{10}	= 512	a_{10}	= 94
A_{11}	= 410	a_{11}	= 76
A_{12}	= 328	a_{12}	= 60
A_{13}	= 262	a_{13}	= 47
A_{14}	= 210	a_{14}	= 39
A_{15}	= 168	a_{15}	= 31
A_{16}	= 134	a_{16}	= 25
ΣA	= 5464		1002
Example 2.			
$B_3 + B_4 + B_5 + B_6$	= 1000	$b_3 + b_4 + b_5 + b_6$	= 693
B_7	= 100	b_7	= 69
B_8	= 80	b_8	= 55
B_9	= 64	b_9	= 44
B_{10}	= 51	b_{10}	= 35
B_{11}	= 41	b_{11}	= 28
B_{12}	= 33	b_{12}	= 23
B_{13}	= 26	b_{13}	= 18
B_{14}	= 21	b_{14}	= 14
B_{15}	= 17	b_{15}	= 12
B_{16}	= 13	b_{16}	= 9
ΣB	= 1446		1000
Example 3.			
$B'_3 + B'_4 + B'_5 + B'_6$	= 10000	$b'_3 + b'_4 + b'_5 + b'_6$	= 693
B'_7	= 1000	b'_7	= 69
B'_8	= 800	b'_8	= 55
B'_9	= 640	b'_9	= 44
B'_{10}	= 512	b'_{10}	= 35
B'_{11}	= 410	b'_{11}	= 28
B'_{12}	= 328	b'_{12}	= 23
B'_{13}	= 262	b'_{13}	= 18
B'_{14}	= 210	b'_{14}	= 14
B'_{15}	= 168	b'_{15}	= 12
B'_{16}	= 134	b'_{16}	= 9
$\Sigma B'$	= 15464		1000

where all factors are known and kept close to all suppositions on which LEA has based his formula. Table 2 gives examples of such stocks. We are presuming that the stocks are kept under such conditions that all factors can be controlled, as in an aquarium.

In example 1 the real number of individuals comprising the year-classes from 3 up to 6 years old is 1000, of 7-year-old fish there are also 1000, and the following age-groups are reduced by 20 %. We will, in the same manner as LEA, exclude the year-classes older than 16 years. The total number of individuals in the aquarium will consequently be 5464.

The corresponding age distribution in ‰ is given in the column to the right. LEA's formula for calculating the fluctuations is

$$\frac{(a_7 + a_8 + a_9 + \ldots\ldots + a_{15})}{b_8 + b_9 + b_{10} + \ldots\ldots\ b_{16}} = \frac{A}{B}$$

ς indicates the proportion of fish which survives from one season to the next, as a mean of the years taken into consideration. A and B is the real number of the stock in two consecutive years. If within a year we remove from our aquarium 20 % of all year-classes, and at the end of the year also put into the aquarium so many recruit fish that we get the same number as the year before, it is easy to see that the nominator and the denominator in the formula will be equal—in other words no fluctuation has occurred. LEA's *formula in this case gives the correct picture of what has happened.*

In example 2 we have removed 90 % of the fish 7 years of age and older. The resultant age distribution is presented, and by calculating the fluctuation by means of LEA's formula we find that the stock has been augmented 2·67 times. *In reality it is reduced from 5464 to 1466.*

In example 3 we have the same age distribution as in our first example as far as fish of 7 years of age and older are concerned, but the recruiting stock comprising the year-classes 3 to 6 years old now number 10,000 instead of 1000.

The age distribution in ‰ is just the same as in example 2, and by using LEA's formula we find that the increase of the stock from example 1 in this case is also 2·67. *Actually the stock has increased from 5464 to 15,464.*—The explanation is that *whether a fish stock receives an unusually great number of recruit spawners, or whether the taxation has greatly increased, the age distribution may be the same.*—Every time we discover a fluctuation in a fish stock by use of LEA's formula, we are therefore confronted with the problem: is the fluctuation due to a higher mortality, or are the recruiting year-classes stronger than normal?

The strange age-composition we now have in the mature stock of the Norwegian tribe of herring, may, in other words, indicate that the stock has received a very strong recruitment during the last two years. On the other hand we may make ourselves advocates for the opposite view and postulate that the recruit spawners are only medium strength year-classes. The fishermen's efficiency in catching the herring has in fact greatly improved in recent years, and the enormous quantities of herring killed during the last 3 years may have resulted in such a great proportion of the older herring being removed that we may regard the strange age distribution as a result of the greatly intensified fishing.

Mr. LEA has used the great fat herring fisheries in 1907—1909, which were based chiefly on the 1904 year-class, as a proof that this year-class was really very strong.

We shall now try to see whether the 1943 and 1944 year-classes have given great yields when the small herring and fat herring fisheries were founded on them.

Figure 3 shows the total landings in Norway of the small herring and fat herring fisheries over the last 50 years.

The small herring consist of the 0- and I-groups. We should therefore have had a very good small

herring fishery in the years from 1943 to 1945. As seen from Figure 3 this was not the case. The fat herring consist of the age-groups II to V, mainly 3 and 4-year-old herring. We might therefore have expected a very good fat herring fishery in the years from 1945 to 1948. But during these years our fishermen have taken an unusually small quantity of fat herring.—I am quite aware that the output of the fat herring fisheries is very irregular, and it is impossible in my opinion to draw any safe conclusion about the stock from the output, but at any rate the output of the fat herring fisheries does not support the theory that the stock has received a strong recruitment.

Another result of a decrease in the stock should be that the older herring especially would become more scarce. Mr. Fridriksson (1944) has suggested that it is the same tribe of herring as that on which the major part of the Icelandic herring fisheries off North Iceland is based. The Norwegian investigations support this view, and it is mainly the older herring which are found in Icelandic waters. During the last three years the Icelandic herring fishery has declined very much, and the opinion of the fishermen operating in Icelandic waters is that the shoals are smaller and much more scarce than before the war.

The conclusion to be drawn is that, especially in the coming years, we have to be careful when calculating the prognosis of the stock. If these 2 year-classes born in 1943 and 1944 continue to predominate in our age determinations, we can safely regard them as strong year-classes.

However, if the coming year-classes also seem to be strong, then we may take it as a danger signal that the stock of herring is decreasing. If we in such case continue to calculate our stock by use of Mr. Lea's formula, we may find a calculated stock which is 100 times as great as the stock was in 1907. At the same time our fishermen will perhaps have difficulties in realizing profits from their efforts.

We have seen it is possible by the use of Lea's formula to conclude that there are fluctuations in a stock of fish, but so far we have no means of determining whether these fluctuations are due to an increase or decrease of the stock. If a rich year-class enters the stock, this fact can only be verified after a period of several years, and it is therefore not possible to calculate a true prognosis of the stock by using Lea's formula. To do this we must first find means of determining whether a fluctuation found by Lea's formula indicates an increase or decrease of the stock.—Here we may get valuable information from marking experiments. I shall try to elucidate this point.

If we mark, say 10,000 specimens every year, 1) and we assume that no fluctuations take place in the stock, then we ought to have a certain number of recoveries per unit of catch. 2) If the stock has diminished the chances of getting a marked herring have increased, and our recoveries per unit of catch should increase at a corresponding rate. 3) If, on the other hand, the stock increases through great

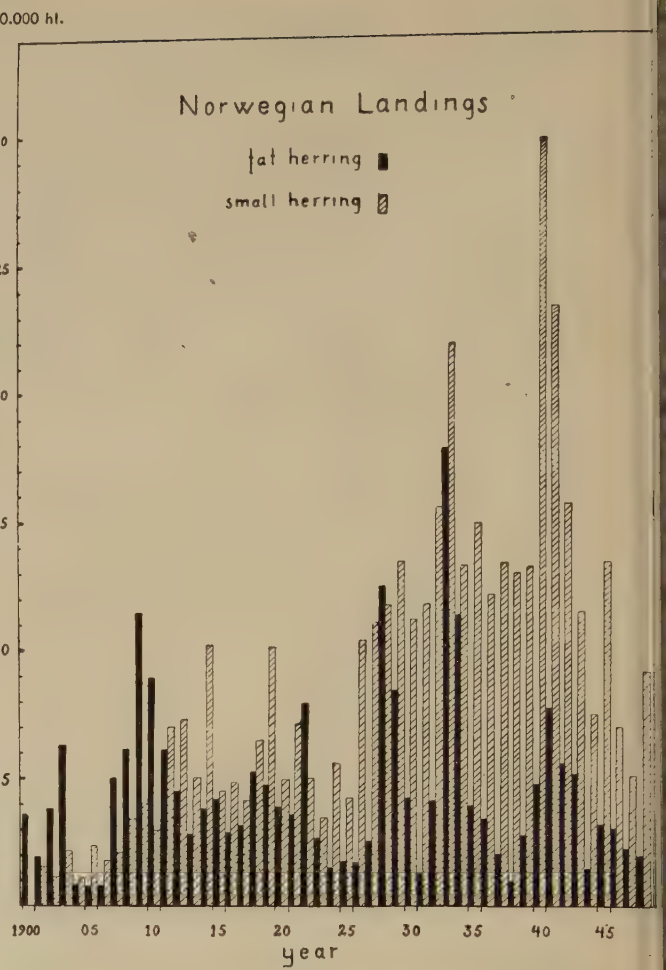

Fig. 3. The total Norwegian landings of small and fat herring in this century.

influx of recruit spawners, e. g., to twice its previous size, the chance of recovering a marked herring is only half of what it was the year before, and we should therefore get a corresponding drop in our returns per unit of catch.

The conclusions are that by the use of Lea's formula we can discover a fluctuation, and combined with standardized marking experiments it may be possible to determine whether this fluctuation means an increase or decrease of the stock.

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3.

Historical Remarks on the Icelandic Herring Fishery.

By

Árni Friðriksson

1. While the demersal fisheries at Iceland can be traced back to the very first years of the settlement in the second half of the 9th century, we have few evidences on herring fishing and on the existence of herring in Icelandic waters.

Some old place-names in the Faxa Bay region might, however, indicate that herring fishing has taken place in the Hvalfjord and in the sounds near Reykjavik in the early centuries, most likely about the year 1000. Another mention on appearance of herring especially off the southern part of the country and in Hvalfjord originates from Olavson's and Paulsen's description of Iceland which appeared in 1772 and must refer to the state of things during the latter half of the 18th century. Other authors from this period also mention herring at Iceland and they appealed to the fishermen to start fishing for them. We have also information on the successful use of stand-nets on the north coast in the period about 1730. In the first two years of the 19th century herring were caught in Faxa Bay and most probably in the fjords of the north coast and we know for certain that herring were abundant at least in some places off the north coast after about 1810. About the middle of the 19th century herring were caught off the north coast by means of a kind of drift-net, which was used in a similar manner as the purse seine is now, but this fishery was abandoned about 1870. From this time and until the end of the century we have reports on the permanent occurrence of herring in Faxa Bay, where a fishery of some importance took place.

In the year 1868 a new period in the Icelandic herring fishery commences. During this year, three Norwegian fishing vessels started fishing for herring in some fjords of the north coast, but, as they did not succeed there, they moved to the east coast fjords where rapidly expanding fishing operations took place. These activities seem to have culminated in 1881, when 187 Norwegian fishing vessels participated. The fishing here in the fjords continued for about 25 years when it was given up as unprofitable. In the years about 1880, large numbers of herring were taken in Eyjafjord on the north coast of Iceland and in the year 1883 herring were reported in great shoals all along the north coast, but did not go into the fjords. This seems to be the beginning of the well-known and rich fishing period off the north coast of Iceland, which has continued until recent years.

It must be noted here, that the Icelandic herring industry is quite a young one, only covering a span of about 60 years, as the first drift-net was operated from an open boat off the east coast in 1890. In 1897 drift-nets were used for the first time off the south and north coasts and in 1899 we had the first drift-net experiment from a decked vessel. At the start of this century the use of drift-nets was common all round the coast and in 1904 the purse seine was introduced. From this time a slow but steadily increasing development took place until 1930, when the government built their first factory. Since then the development has continued with great speed.

2. I must now make a few remarks on the Icelandic herring. As far as we know it consists of three tribes, by far the largest of which is fished off the north coast during the summer months. This tribe, which is a spring spawning one, is now, by many scientists, considered to belong to the Norwegian large spring herring type, a part of which makes the long migration to Iceland in order to recover after spawning and prepare for the next spawning in Norwegian waters. Recaptures of herring, tagged at the west coast of Norway, off the north coast of Iceland, and of herring, tagged off north Iceland, at the west coast of Norway, confirm this theory.

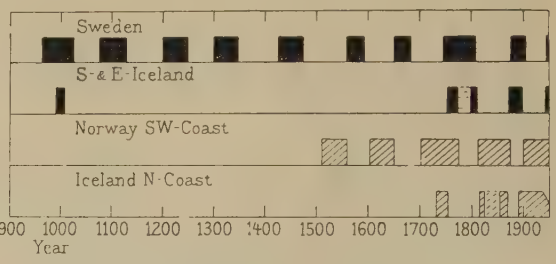
Another tribe of herring is the summer spawning one off the south and south-west coasts of Iceland. It does not migrate to the north coast to any considerable extent during summer and is rarely found represented in the catches of the north coast. The third tribe is a spring spawning herring, the spawning of which takes place off the south coast during March and April. It can be distinguished from the

north coast herring proper by the higher number of vertebrae, smaller size, lower age, and, last but not least, by the types of the scales. This tribe may be intermixed with the north coast herring during the season but normally to a small extent, comprising only 1 or 2 percent. of the total catch. I should like to emphasize now, that this particular tribe has been unusually predominant during the last five years. This newly increasing stock originates largely from the very rich year-class of the year 1944. This tribe gave rise to an entirely new extensive fishery during the winter 1947—1948 and partly also in 1946—1947, when enormous shoals penetrated, probably brought in by ocean currents, into the fjords and sounds of Faxa Bay, especially the Hvalfjord. In the summer of 1948 this herring amounted to more than 30 percent. in the catches off the north coast and during 1949 it made about 13 percent. there. Hand in hand with this development, we have had a more disastrous one, namely an increasing failure of the north coast catches since 1945, that year included. Another trend is also worth noting, namely an increasing occurrence of herring in the fjords of the east coast, especially during this last summer.

3. It has been described by K. A. Andersson and other Swedish scientists how the great inshore herring fishery off the west coast of Sweden has fluctuated over a period of about ten centuries[1]). In historical times there have been 9 rich periods inshore of the belt of skerries, alternating with periods with very little or no herring. A remarkable feature is the fact, that a new herring period, the 10th one in historical times, seems to have begun during recent years. Information on the fluctuations in the large spring herring fisheries of Norway go back to the 16th century since when rich herring periods on the west coast have alternated with series of years with few or almost no herring. It has been pointed out by Otto Pettersson[2]) and has recently been emphasized in a newspaper article by G. Rollefsen, that the fishing periods off the west coast of Norway do not occur simultaneously with rich years off the west coast of Sweden, but tend clearly to alternate with these[3]). Thus herring were practically absent from the Norwegian banks during the last 20 or 30 years of the last century whereas the last rich herring fishing in Sweden took place in 1877—1906 and after this time we have had a rich fishing period in Norway and a bad one in Sweden.

4. I will now finally turn over to the Icelandic herring and try to summarize what we know about its occurrence.

According to the oldest records, it seems that we had herring fishing in the fjords of Faxa Bay about the year 1000 and if that is true, it will coincide with the oldest known herring period in Sweden which took place at the end of the 10th and in the beginning of the 11th century. Thereafter we know practically nothing about the occurrence of herring until about 1730 and the following years when herring were present off the north coast of Iceland. This was about the middle of a Norwegian spring and large herring fishing period which lasted from 1700—1784. The next herring occurrence in Icelandic waters was in Faxa Bay, in the year 1750 and again in the same place in 1801 to 1802. The interval between those two periods may be illusory owing to lack of fishing activities and failing knowledge of the presence of herring when not in inshore waters. I am inclined to think that we have to deal with one continuous herring period from 1750 to, at least, 1802, which again agrees very well with the simultaneous herring fishing in Sweden in 1747 to 1809. We have evidence of the occurrence of herring off the north coast in



Schematic Survey of Herring Periods at Sweden, Norway, and Iceland.

1810 and the following years and again in 1850—1870. Most probably we have again here to do with a continuous period which then almost quite covers a corresponding Norwegian fishing period which lasted from 1808—1876. I have now only to mention the two last fishing periods, which succeeded each other and which we are well acquainted with owing to their great economical importance. During the first one which lasted from about 1868 until 1900 or so, the herring occurred particularly in the fjords of the east coast and in Faxa Bay, whereas during the other, which seems to have commenced in 1883 and has lasted until now, the fishing has taken place in the open sea off the north coast of Iceland. The first-named of these two periods coincides perfectly with the last fishing period of Sweden in the years 1877—1906 and the second is in fine agreement with the herring period of Norway which is reported to have commenced about 1883 and is still going on.

5. The herring fishing off the north coast of Iceland has partially failed during the last five seasons, and at the same time, the local stocks of the south coast, especially the spring spawning herring there, have increased enormously. We are not in possession of sufficient scientific material or historical records, which are reliable enough to enable us to make a forecast for the future, even for the immediate future. But when considering the development of the Ice-

[1]) K. A. Andersson: Sillens vandringar och sillfisket på västkusten. Kungl. Lantbruks Akademiens Tidskrift. 1948, Nr. 1—2.

[2]) Journ. du Conseil, I, 4, 1926.

[3]) A. C. Johansen: On the Migration of the Herring. Journ. du Conseil, Vol. II, No. 1, Copenhague 1927.

landic herring fisheries during recent years, it seems to me that we are now facing a turn-over from a good and long-lasting north coast period which has lasted for some 60 years or more, to a more uncertain state of things when the fishing operations must be transferred to the two local now flourishing stocks which gave so many good catches during the latter half of last century. It seems to me to be an outstanding feature, that there is a positive correlation between large-scale occurrences of herring off the north coast of Iceland and the south-west coast of Norway which can easily be explained through the relationship or perhaps we should say, the identity of these stocks. But what is more peculiar is the negative correlation between the behaviour of this combined stock on the one hand and the west-Swedish fishing periods on the other. The great coastal fisheries of Sweden seem to take place at the same time as the Icelandic herring fisheries in the south and east, especially in the fjords, which again seem to be alternating with the occurrence of the Atlanto-Scandinavian herring stock in north-Icelandic waters.

It would certainly be worth while to make further investigations on the positive or negative correlation of the fisheries named above. If the results of the investigations should confirm, what has been said here, and I feel they would, we should have to solve two problems: 1) Why do the fishing periods at Sweden and at Iceland in other places than off the north coast coincide, and 2) Why do the fishing periods of Sweden etc. on the one hand and those of west Norway and north Iceland on the other hand, alternate?

I think it would be most reasonable to assume that the reason should be sought in fluctuations of the ocean currents, which in turn would give good living conditions to one tribe of herring and bad ones for another at the same time. It would not even be sufficient to know this for certain. We have to understand the whole mechanism which is responsible for the fluctuations.

4.

Present Herring Problems of the Swedish Herring Fishery.

By

K. A. Andersson

I. The Type of Herring Scales as "Race" Character.

I have previously tried to show that the autumn spawning herring caught in August and September on Fladen Ground are the same herring that are caught during the following winter in the eastern Skagerak and off the west coast of Sweden. The reasons that I have given are that the herring in both areas have the same number of vertebrae, viz. about 56·50, and that a very large proportion of this herring in both areas have small central fields on the scales, which is remarkable in autumn spawning herring. This problem I treated at the Special Scientific Meeting on Herring in Stockholm in 1946 (Rapp. et Proc.-Verb., Vol. No. 118). In order to explain the occurrence of small central fields on autumn spawning herring I assumed that the first winter ring had arisen already during the first winter, i. e. that the scales had been laid down already before the first winter. Consequently if the winter rings are counted when the age of such herring is determined, the age will be one year too great. The correctness of this assumption is supported by the fact that, in determining the age of this autumn spawning herring, the age of herring with small central fields is one year higher than that of the herring with large central fields (see the diagram). This evidently applies at all events in the case of dominant year-classes. If my assumption is correct, the age read from the scales with small central fields should be reduced by one in order to obtain the correct age. A herring with small central fields that shows by its scales an age of, say, four years, would thus have been hatched during the same autumn as a herring that with large central fields exhibits an age of three years, the only difference being that the former had been hatched a short time earlier.

The difference in length also confirms the correctness of my assumption. If a herring with small central fields is, according to the scales, four years old and thus one year older than a herring with large central fields that, according to the scales, is three years old, then the former should be 1—2 cm. longer than the latter; but that is by no means the case. I will illustrate this by giving some examples. Dr. H. Wood, Aberdeen, has been good enough to lend me a great many series of scale samples from Scottish waters. The average lengths are calculated as follows.

Comparison of Length of Herring from Scottish Waters.

(Age determined according to the number of winter rings on the scales.)

Age	Number measured	Central fields	Average length cm.	Difference cm.
Herring from Wick, 7. September 1933.				
3	25	large	24·2	
				1·2
4	12	large	25·4	
				0·4
5	95	small	25·8	
				0·9
5	47	large	26·7	
				0·1
6	20	small	26·8	
				0·9
6	10	large	27·7	
Herring from Fraserburgh, 22. August 1939.				
3	44	large	25·1	
				0·2
4	36	small	25·3	
				1·2
4	28	large	26·5	
Herring from Peterhead, 5. September 1945.				
3	25	large	24·7	
				0·8
4	25	small	25·5	
				0·9
4	30	large	26·4	

In one or two cases the number of herring measured is too small to be satisfactory. We see that herring with small central fields and an age by their scales of, for instance, four years are only 2—8 mm. longer than a 3-year-old herring with large central fields, but considerably smaller than a 4-year-old one with large central fields. The same result is obtained, if a 5-year-old herring with small central fields is compared with a 4-year-old herring with large central fields. This seems to me to provide support for my supposition that herring with small central fields obtain their first winter ring already during the first winter of their lives.

A further support for this assumption will probably also be provided by the fact that in the eastern Skagerak one finds in the herring exhibiting a length of 18—21 cm. a mixture of 2-year-old herring with large central fields and, from the scales, 3-year-old herring with a small central field. Then, however, the latter is on an average slightly larger than the former. In a sample taken on 11. February 1916, off the Swedish west coast the average length was 19·0 and 19·8 cm. respectively. It seems likely that these two herring groups are hatched in the same autumn, but the one with small central fields some time before the other.

This problem is of great importance for age determination. If my assumption be correct that the first winter ring in autumn spawning herring with small central fields emerges already during the first winter, then, in this herring, the first winter ring should not be counted. The question of the emergence of the first winter ring in this herring is also of supreme importance for determination of the year when a year-class comes into being. These two types of herring scales are, in my opinion, of great help in identifying herring that make long migrations.

In my opinion, there are accordingly good reasons for assuming that the first winter ring in autumn spawning herring with small central fields in the north-western North Sea emerges during the first winter, but I find it nevertheless desirable that the correctness of this assumption be proved by showing that this herring has scales already the first winter. As far as I know, this has not yet been done. I am quite aware that it is very difficult to catch herring in such a stage, but I would suggest that this problem be taken up for further investigation in the North Sea.

II. The Water Temperature on Spawning Grounds.

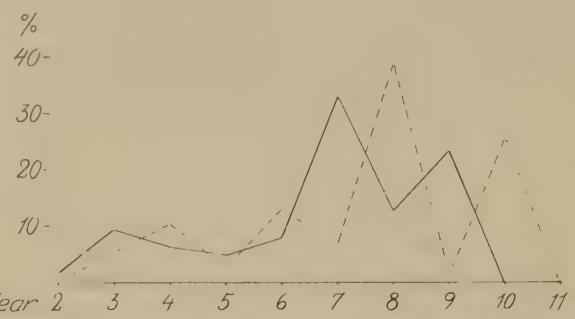
At the Meeting of Herring Experts at Charlottenlund in October 1945 (see Rapp. et Proc.-Verb., Vol. No. 116, 2nd Part, p. 20), it was recommended that hydrographical investigations should be undertaken on the spawning grounds of the herring at the time of the spawning season.

The importance of such investigations was emphasized. It is possible that the various so-called herring races spawn in different hydrographical environments. If that be so, the different characters of the "races" could be a result of the different environments.

In a paper in *Annales Biologiques* Vol. V, p. 80, I endeavoured to show that we have a population of spring spawning herring on the Fladen Ground, in the area off Egersund and in the eastern Skagerak. Its number of vertebrae averages 57. Also in some other respects the herring in the said places were alike. The Norwegian spring spawners have an average number of 57·35. It would be of great importance to obtain close knowledge of the hydrographical conditions in the spawning places of these two populations of spring spawning herring. It is possible that different hydrographical conditions, e. g. temperature, might cause the difference in the number of vertebrae.

I would suggest that this problem be investigated.

In this connexion the Herring Meeting mentioned above recommended that experiments regarding the hatching of herring spawn and the rearing of herring fry should be promoted in order to study how far



Age Composition of Herring from the Gullmar Fjord, west coast of Sweden, 15th January 1949.
- - - - - Small central field.
—— Large central field.

race characters are dependent upon temperature and other physical conditions. I will emphasize the importance of such investigations and recall that Dr. Vedel Tåning arrived at excellent results through his hatching and rearing experiments on sea trout.

III. The Influence of the Hydrographical Conditions upon the Stock of Herring.

1. In an earlier paper[1]) I have endeavoured to show that, as far as the autumn spawning herring in the Sound and the southern Baltic is concerned, a relatively high temperature in September and October, i. e. the spawning period, and during the following winter is very important for the initiation of a strong year-class. Other factors have been shown to exert a great influence on the strength of the year-classes, e. g. the supply of food during certain periods of the life of the young fry.

As the strength of the year-classes is of great significance for comprehension of the fluctuations in the herring fishery, it seems urgent for investigations to be carried out to increase our knowledge of the reasons for the fluctuations in the strength of the year classes.

2. In my above-mentioned paper I showed that the breadth of the summer zones on the scales of herring from the southern Baltic varied very strongly. This variation is obviously a result of a variation in the rate of growth during different years. I tried to

[1]) The Stock of Herring in the Sound and the Southern Baltic in the years 1940—1944. Ann. Biol. Vol. No. II, p. 166.

prove that there existed a close correlation between the growth and the water temperature, so that a low temperature brought slight growth and narrow summer zones and a high temperature strong growth and broad summer zones. This applied to both autumn and spring spawners.

This correlation ought to be more closely studied.

3. In another paper[1]), I have shown that the growth-rate of herring in the Sound has been subject to great variations during different periods of years. My investigations proved that a considerable increase in growth-rate took place during the years when the stock had become smaller. Most likely, I said, this difference in the growth-rate was due to the variations in the quantities of food available for each individual when the stock was dense and when it was poor. In my above-mentioned paper in Ann. Biol. Vol. No. II, I continued these investigations and was able to show that a considerable decrease in the growth-rate took place during 1940 when the density of the stock had again become greater. There is, unfortunately, a gap in the investigations, namely that I have not investigated whether an increase or decrease in plankton can have caused the variation in the growth-rate of herring. The question of these variations seems to be highly interesting. If these changes in the rate of growth within a certain area should definitely prove to depend upon the greater or lesser density of the stock it should be possible through investigations of the length of herring of a certain year-class to get an indication as to the greater or lesser abundance of this year-class.

I should like to suggest that this problem be taken up for more general investigation.

[1]) The Stock of Herring in the Skagerak, the Kattegat and the Sound in 1939. Ann. Biol., Vol. I, page 161.

IV. The Migration of Herring.

It is well known that the herring fishing in the eastern Skageråk is subject to very great fluctuations. I have tried to show that these fluctuations depend upon the quantities in which the autumn spawning Fladen herring migrates into the eastern part of the Skagerak. In order to obtain reliable proof of the migration of the herring between the west coast of Sweden and the North Sea it is necessary to carry out marking experiments on the herring concerned. During last winter we made our first marking trials with Lea's hydrostatic marks: these seem promising and we are going to continue these experiments on a larger scale. (See Dr. Hans Höglund's paper on p. 52.)

There is one difficulty with this herring marking and that is that the autumn spawning Fladen herring during the present fishing seasons never occur unmixed either on the Fladen Ground or in the eastern Skagerak. They are always more or less mixed with spring spawning herring and in the Skagerak also with the Kattegat autumn spawning herring. But by repeated markings on a larger scale we shall be able to gain a good idea of the migration of the types of herring concerned.

It seems very desirable for tagging experiments on herring to be carried out in all countries bordering the North Sea.

5.

Migrations of the Herring in the Waters round Denmark.

By

Aage J. C. Jensen

The Identification of the Races by aid of Racial Characters.

The many investigations into the races of herring which have been carried out furnish a reliable basis for distinguishing between the different races. In some cases observations on the ratio between the widths of the first growth zones in the scale may be useful for confirmation of the results. The Danish investigations have been specially concerned with establishing the origin of tiny herring, with only one or no winter ring, i. e., their hatching area; in this case the scale cannot be used to distinguish between spring and autumn herring.

It is true that hatching experiments have shown that the racial characters vary according to the temperature at spawning time. The racial characters of herring spawning at the same season and within the same locality, have practically always the same average values year after year with deviations so small that no difference can be established statistically. But it should always be borne in mind that statistically significant anomalies within individual year-classes have been established by Lea[1]), Rounsefell & Dahlgren[2]), Runnström[3]), and Tester[4]). As regards the autumn herring at Bornholm I was able to point out such anomalies[5]). They must be explained as consequences of abnormal temperature conditions at hatching time.

Among the spring herring especially, the racial characters are the same over comparatively wide areas, so that we may take it that they are herring of the same race spawning over a particularly large area, with the main centre of spawning varying in position within the area from year to year. This is no doubt the case with the spring herring of the central Kattegat and the Belt Sea. At any rate, fluctuations from year to year in the yields of fisheries within the individual sections of the area seem to confirm this view. Though it has not been proved, the same may also be true of A. C. Johansen's race of "Atlanto-Scandian spring herring". These herrings show the same racial characters over very large areas, but whether they do in fact belong to the same race can only be ascertained by means of marking; the herring must be marked during the spawning season of one year and be recaptured during the spawning season of one of the following years.

V. S.—V. P. and V. S.—K_2 Diagrams.

In many cases it is necessary to consider the combination of the racial characters V.S., V.P. and K_2 in order to decide to which race the fish of a given sample belong, and the most practical procedure is then to join them in diagrams. If we combine samples of mature herring in this way, they tend to group themselves into their constituent races. The spread within each group or cluster is principally due to random variation, often accentuated by the small size of the sample, but the variation must be ascribed, to some extent, to real differences in racial characters of the individual year-classes due to the influence of temperature.

The data on mature herrings used in the diagrams 1—6 are from Johansen 1915—1930, Schnakenbeck 1924—25, Altnöder 1926—28, Wood 1933—36,

[1]) Einar Lea: Age and Growth of the Herring in Canadian Waters. Canad. Fish. Exped. 1914—15 under the direction of Dr. Johan Hjort. Ottawa 1919.

[2]) G. A. Rounsefell & E. H. Dahlgren: Fluctuations in the Supply of Herring (*Clupea pallasii*) in Prince William Sound, Alaska. U.S. Bur. Fish., Bull. XLVII, No. 9. 1932.

[3]) Sven Runnström: Racial Analysis of the Herring in Norwegian Waters. Rep. Norw. Fish. and Mar. Invest. VI, 7. 1941.

[4]) A. L. Tester: Variation in the Mean Vertebral Count of Herring (*Clupea pallasii*) with water temperature. Cons. Internat. Explor. Mer, Journ. du Cons. XIII, No. 1. 1938.

[5]) Aage J. C. Jensen: The Herring at Bornholm. Ann. Biol. II, pp. 155—58. 1946.

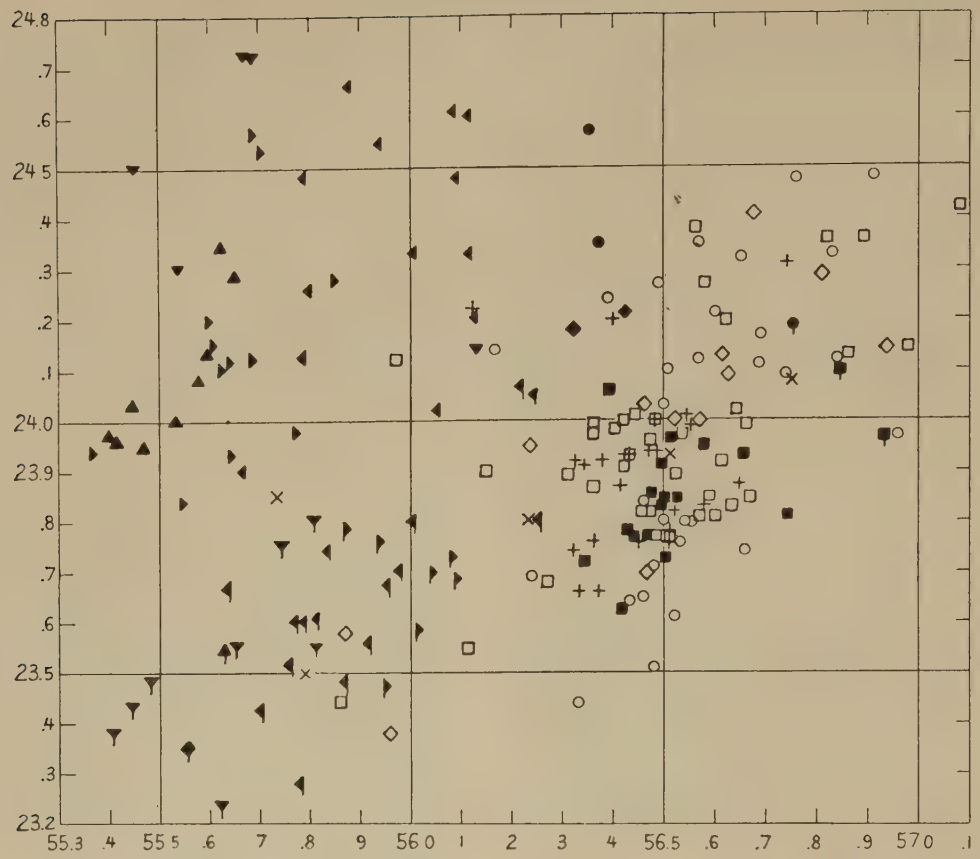


Fig. 1. V.S.-V.P.Diagram. Samples of young, immature herring and of large herring, respectively, from the Skagerak and the northernmost Kattegat, compared with samples of races spawning in the North Sea, the Kattegat, the Belt Sea, and the Sound. For explanation of signatures, see Fig. 2.

Gilis 1946—47 and myself since 1937, for the Baltic (Fig. 7) from Heincke, Hessle and myself. My data on immature herrings are supplemented by some few samples from Altnöder and Johansen.

In Figures 1 and 2 and in Figures 5 and 6 V.S.—V.P. and V.S.—K_2 values have been shown for samples of mature herrings from the North Sea, Skagerak, Kattegat, the Belt Sea and the Sound. It is seen that in the Kattegat and the Belt Sea the V.P. value seems to be a better character for distinguishing between spring and autumn spawners than the K_2. Although the overlapping of the K_2 values of autumn and spring spawners may be in some cases due to the small size of the sample, it has also been found with fairly large samples (of about 200 indiv.).

Diagrams such as these can be used to analyse a sample of herring into its component races. Thus from them, in most cases, it can be decided immediately whether a sample of immature herring belongs to a definite race or is a mixture of two races; it is also possible to determine the proportion of the mixture.

Indigenous and Foreign Races of Herring in the individual areas of the Danish waters.

The south-eastern North Sea.

Large quantities of young herring in this area were regularly caught with stow-nets by German vessels. There are only a few Danish racial analyses of these young herring caught in the Horns Reef area. One such analysis was performed by Dr. A. C. Johansen in September—October 1922. These herring had a V.S. of 56·35 (115), a V.P. of 23·95 and a K_2 of 15·22[1]). Heincke in 1877—91 found young herring of the same racial character at the mouth of the Elbe. In other words they were herring spawning in summer or autumn in the western or north-western North Sea and must be presumed to have been Dogger Bank herrings. Minch herring have a lower K_2, Downs herring higher V.S. Another sample taken in August 1944 off Esbjerg had a V.S. of 56·47 (174) and a V.P. of 23·72. These were from the Dogger or north-

[1]) Number of fish in brackets.

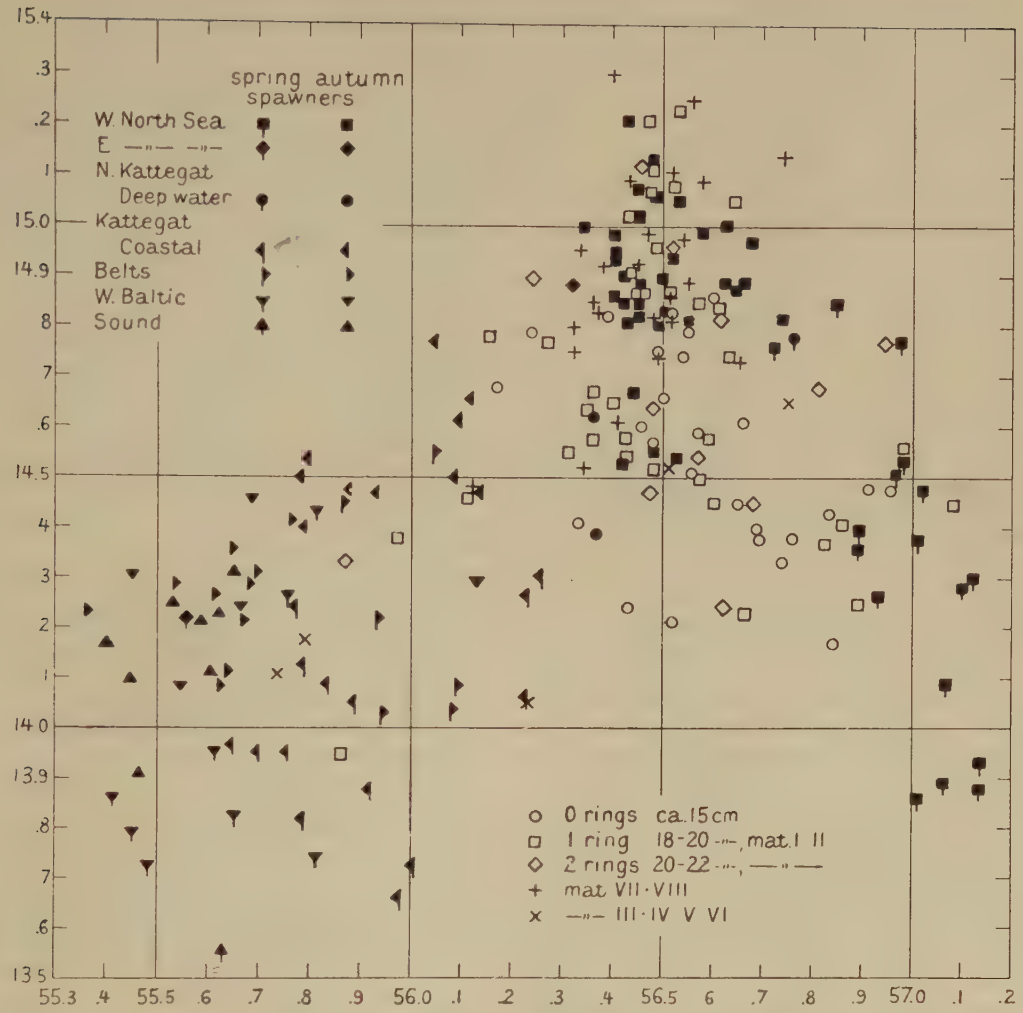


Fig. 2. V.S.-K_2 Diagram. Samples as in Fig. 1.

western North Sea. Three samples from off Esbjerg taken in July—August 1949 had a V.S. of 56·52 (263), a V.P. of 23·80 and a K_2 of 14·79. They originated in the north-western North Sea. Also in this area, there are probably the young of the Downs herring and of the local spring herring from the south-eastern coasts of the North Sea.

The Skagerak and the northernmost Kattegat.

From autumn to spring, Swedish fishermen have for many years been fishing for large herring, of which the great majority were spent, and also for small herring. The development of, and changes in, the fishery were described by Dr. K. A. Andersson[1]).

[1]) K. A. Andersson: Some remarks on the fluctuations in the Herring fishing on the west coast of Sweden. Rapp. et Proc.-Verb. CXVIII. 1947.

From the thirties onwards, Danish fishermen joined in the fishery for large herring. Dr. A. C. Johansen has demonstrated that most of the large herring caught here are summer and autumn spawners from the western North Sea. Among these herring there may be smaller quantities of coastal spring herring from the Kattegat and further, Johansen found here, in a few samples, the winter herring of the northern Kattegat. This herring spawns at Læsø in comparatively deep water and has a V.S. of about 56·75. Both near the coast of Bohuslän and off Hirtshals were found local coastal spring herring having a V.S. of about 56·25. These spawn on the coast of Bohuslän, in the Aalbæk Bay S. of the Skaw, and on the Danish coast of the Skagerak. Of even rarer occurrence are herring of races spawning in the Belt Sea, but it must be noted that in April 1918 a pound-net sample taken at Frederikshavn was found to contain some herring

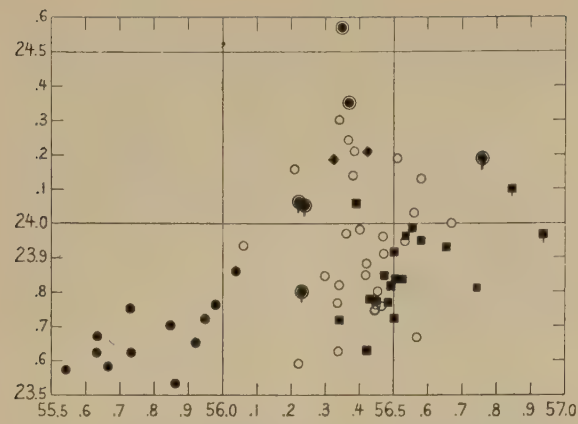


Fig. 3. V.S.-V.P. Diagram. Samples of immature herring from the Limfjord compared with samples of races spawning in the Limfjord, the North Sea, and the northern Kattegat. For explanation of signatures, see Fig. 4.

of 18—23 cm. length with V.S. 55·56 (190) and K_2 14·30, i. e. herring of the western Baltic type.

Since the end of the thirties an extensive Danish fishery for young herring has also developed in the Skagerak and the northern Kattegat; these fish are mostly used for processing. This fishery is pursued by Danish fishermen from November to March in the area between Læsø Rende and Hirtshals.

The diagrams of Figures 1 and 2 show the results of the racial analyses made during 1939—49 of young immature herring with 0, 1 and 2 rings, of maturities III—IV and of spents and recovering spents, respectively. The diagrams show further the racial characters of the races that we may expect to find among the herring taken during the fisheries in the Skagerak and the northernmost Kattegat, mentioned above, determined mainly from herring of maturity V and VI but including in some of the samples from the western North Sea also herring of maturity IV and VII.

As will be seen the majority of the large spent herring and recovering spents taken in the Skagerak belong to the summer and autumn spawners of the western North Sea, mostly from between Shetland-Peterhead-Fladen Ground and the Berwick coastal areas (Wood's racial classification). Only a few samples contained herrings from the Minch with a low K_2 value, or from the Lowestoft area with a high V.S. value.

It is worth noticing that the Kobbergrund herring was not met with in any of the samples of large Skagerak herring dealt with in the diagrams which include only those in which more than 45, generally about 100 herring, were examined. Among the samples having V.S. values ranging between 56·3 and 56·4, the V.P. value is always too low and the K_2 value is in most cases too high for this race (or for the autumn herring of the Jutland Reef): These samples must consist of North Sea herring intermixed with coastal herring from the Kattegat (or the Belt Sea).

In most samples the 0-, 1- and 2-ringed immature herring of the Skagerak and the northernmost Kattegat have characteristics agreeing with the summer and autumn spawners of the western North Sea, this being particularly so with 1-ringed fish (see Figs. 1 and 2). Some conform with the spring spawners of the Atlanto-Scandian race group and with their relatives: the Forth spring spawners which have a little lower V.S. value and a little higher K_2 value, and also with the "winter herring" (Johansen) of the northern Kattegat where the V.S. value is still lower and the K_2 still higher. There may also be some spring spawners from the Norwegian Skagerak coast, which have a V.S. of 56·9—57·1 (Oslofjord included), but where the V.P. and K_2 values are unknown. It appears from the figures that other samples are mixtures between these autumn and spring spawners.

We do not know the V.P. or K_2 values of the Norwegian spring herrings which have about the same V.S. values as those from the coasts of Scotland, and therefore we cannot decide whether the young herring with a V.S. value higher than 56.8 (Atlanto-Scandian type) originate from the coast of Norway or from the Scottish area.

From the distribution of the currents it is most likely that these young herring originate from the Scottish area but it is also possible for the young of the Norwegian herrings to be carried to the fishing grounds by the whirls in the western Skagerak and the north-eastern North Sea.

There is a pronounced difference between the 0- and 1-ringed summer and autumn spawners which visit the Skagerak annually from the western North Sea: the 0-ringed fish belong to the races with a K_2 value lower than 14·8, and most of them conform

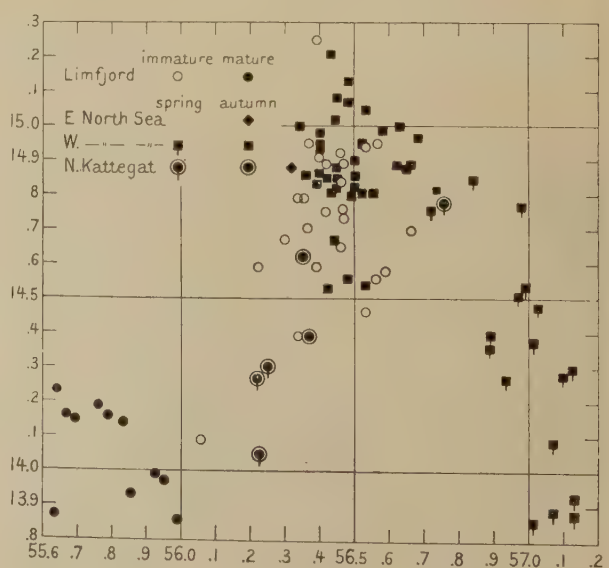


Fig. 4. V.S.-K_2 Diagram. Samples of herring as in Fig. 3.

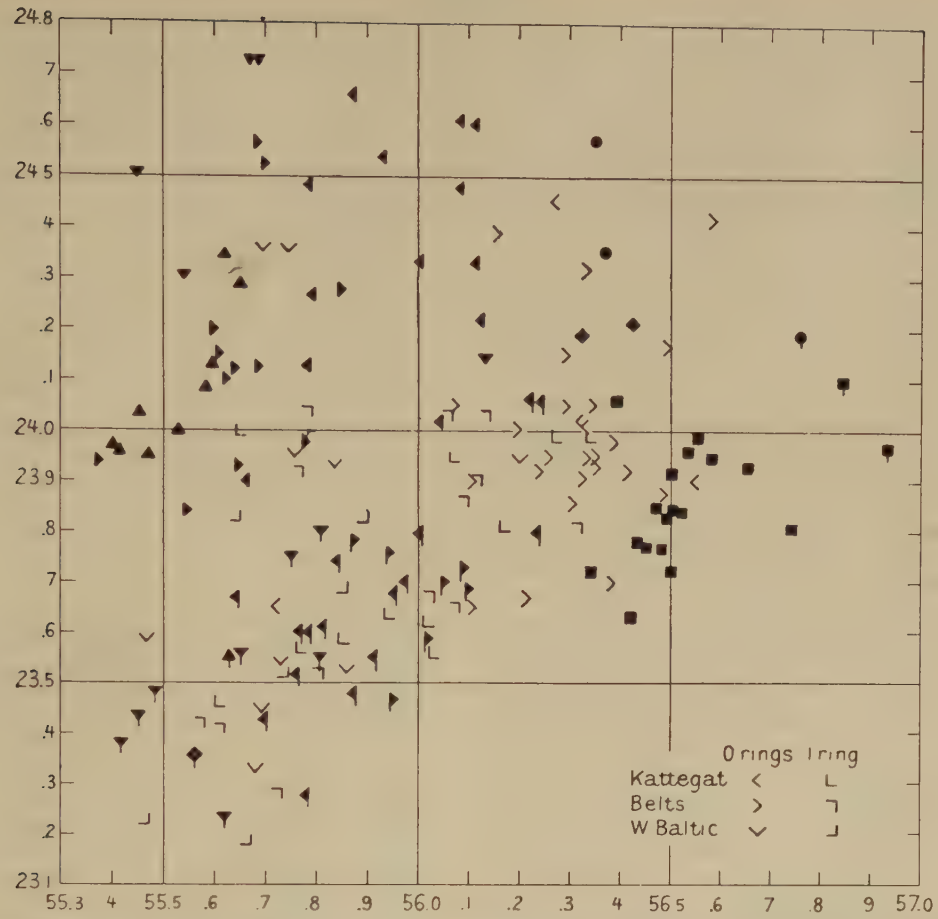


Fig. 5. V.S.-V.P. Diagram. Samples of young immature herring from the central and southern Kattegat, the Belt Sea and the Sound compared with samples of races spawning in the North Sea, the Kattegat, the Belt Sea, and the Sound. For explanation of signatures for mature spawning herring, see Fig. 2.

with the Minch herring. It may seem unlikely that this race group should be especially richly represented in the Skagerak and therefore it must be taken for granted that the comparatively low K_2 values of the 0-ringed fish are due to mixtures with local races. In other words we may conclude that the invasion from the western North Sea begins with the 0-ringed fish but continues with 1-ringed herring to such an extent that fish with high K_2 values become dominant among the 1-ringed fish found in the area. The 1-ringed fish seem to represent all groups of summer and autumn spawners from the western North Sea from Shetland to the Lowestoft area.

Of the 0-ringed fish one sample has a V.S. between 56·3 and 56·4; its V.P. of 23.44 (123) and K_2 of 14.41 (185) indicates that the fish were spring spawners from the Jutland coast of Skagerak or the northernmost Kattegat. A sample of 0-ringed fish which has a V.S. of 56·24 (72) may consist of North Sea autumn spawners deviating on account of the small number; one with V.S. = 56·17 (41) may belong to the coastal spring herring from Bohuslän and northern Jutland or to coastal autumn herring from the Kattegat.

Several samples of 1-ringed fish have a V.S. lower than 56·40. One with a V.S. of 55·86 is seen to consist of spring spawners from the Kattegat or the Belt Sea (or possibly from the Limfjord or Ringkøbing Fjord), and one with a V.S. of 55·97 are autumn spawning coastal herring from the Kattegat. The V.P. of each of those with V.S. values between 56·3 and 56·4 is considerably lower than is the case with Kobbergrund herring. A few of these may be autumn spawners from the eastern North Sea but the majority have too low a V.P. value and must be mixtures with the Kattegat or Belt Sea fish and to a smaller degree with coastal autumn spawners from this area. Coastal spring spawners from Bohuslän and northern Jutland with a V.S. of about 56·25 may also be represented in these mixtures. It must be noted that in a few

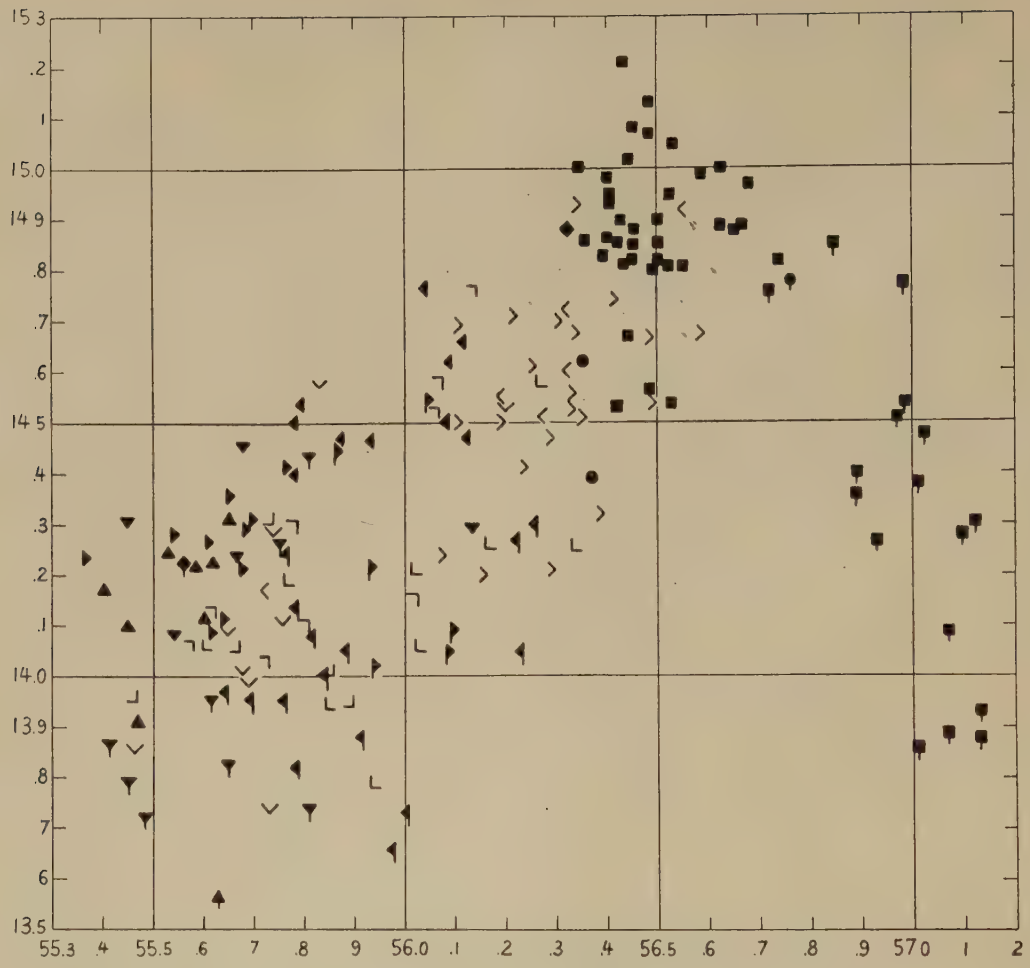


Fig. 6. V.S.-K_2 Diagram. Samples as in Fig. 5. For explanation of signatures for young herring, see Fig. 5, for mature (spawning) herring, see Fig. 2.

Skagerak samples were found mature herring of the same racial character as the southern Kattegat and Belt Sea spring spawners and so they do not seem to have migrated from very far away.

The Limfjord.

The samples from the Limfjord have been combined in Figures 3 and 4 in the same way as have been those from the Skagerak. A noticeable difference in racial characters is observed between the mature Limfjord-herring and the young immature herring. The latter, which form the basis of a very extensive fishery, are mainly the young of the summer and autumn spawners of the western North Sea, although, in some cases, autumn herring of the west coast of Jutland and Thyland herring may be present. In a smaller number of samples there is a greater or smaller admixture of spring herring from the Limfjord.

In other words there is a very considerable immigration into the Limfjord of the young of the summer and autumn herring of the western North Sea.

The southern Kattegat and the Belt Sea.

Only among the immature young herring of these areas do we find fish of races other than those belonging to the areas. The samples of young herring are shown in Figures 5 and 6 together with samples of mature herring of the races to which the young may belong. It is seen at once that the racial character of the young herring is totally different from that of the herring spawning in the area. In fact only the 0-ringed from the western Baltic consisted almost exclusively of indigenous fish. Some samples consist purely of autumn herring of the North Sea, some are no doubt Kobbergrund herring, and others again undoubtedly local spring herring from the northern Kattegat with a V.S. of about 56·25, a V.P. of about 23·9 and a K_2 value of about 14·2; but several samples must be

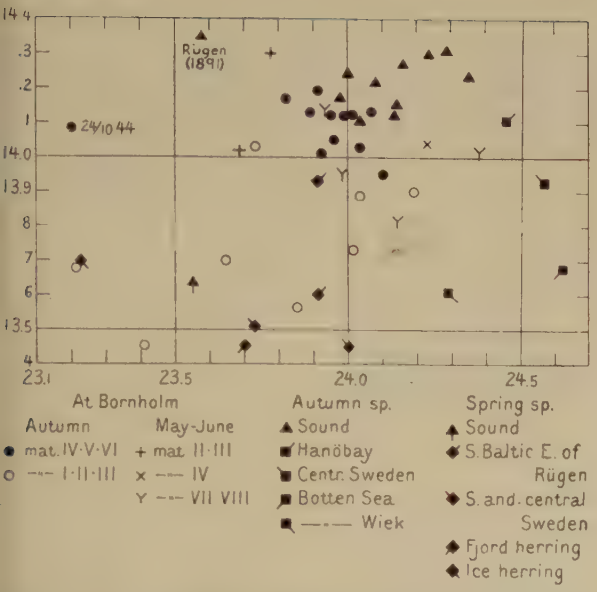


Fig. 7. V.P.-K_2 Diagram. Samples of herring of various maturities caught round Bornholm compared with samples of races spawning at other places in the Baltic and the Sound. For the Swedish fjord-herring the V.S. is lower than for the Bornholm herring, for the Ice herring it is higher.

mixtures of North Sea herring and coastal autumn fish from the Kattegat and the Belt Sea. In other words we find here a very considerable immigration of young from the north, partly from the North Sea. It appears that the fry of the Kobbergrund herring are mainly found to the south of the spawning places, since they were present in only a few samples of mostly 0- and 1-ringed fish in the Skagerak.

The Sound.

From this area mostly adult herrings were examined. The majority were normal Sound herrings but sometimes included spent herring from Bornholm, Hanöbay and the southern Kattegat or the Belt Sea. In some cases Baltic spring herring made up the greater part of the catches. In July 1943 considerable quantities of young herring occurred in Køge Bay where they were subjected to fishing. These herring, about 11 cm. in length, were no doubt autumn herring from the western North Sea (V.S. 56·39 (203), V.P. 23·91), possibly with a slight admixture of fish from the Kattegat or more southerly areas.

Bornholm.

From this area only grown-up herrings were examined because no small herrings are taken here. The samples are compared in Figure 7. The majority of the spring and autumn herrings in this area have a V.S. of about 55·5, and therefore the V.P.—K_2 diagram is given here. The mature herrings are typical autumn herring of Bornholm, and this is partly true also of the herrings of maturity VII—VIII in autumn. In two catches from W. of Bornholm in June, the V.P. and K_2 values differed distinctly from those of the Bornholm herrings (the difference was about 3 times the standard error of the difference), and there must be supposed to have been an admixture of autumn herrings from the Swedish coast. The immature herring (maturity I—II—III), however, in most of the samples differ from the autumn herring of Bornholm and must be intermixed with autumn herring from other areas of the Baltic or with Baltic spring herring. No immigration of immature herring from the Kattegat or the Belt Sea to these areas is found.

6.

Herring Fishery in the Netherlands.

By

B. Havinga

The herring is by far the most important fish for the Dutch sea fishery, both in quantity and value (Table 1). More than 50% of the total landings consist of herring, and its value generally exceeds the value of the total catch of demersal fish.

Until 1930 all the catches were landed by vessels fishing with drift-nets, but in 1930 trawlers started fishing with the herring trawl and the quantity landed by trawlers has been increasing ever since (Table 1).

Table 1. Landings and Value of North Sea Herring and Demersal Sea Fish in the Netherlands by Dutch vessels.

(Quantities in millions of kg. values in millions of guilders.)

Year	Herring				Demersal fish	
	Drift-net		Trawl			
	Quantity	Value	Quantity	Value	Quantity	Value
1891.....	43	6·0	—	—	—	—
1895.....	58	6·2	—	—	—	—
1900.....	53	7·3	—	—	—	—
1905.....	76	10·1	—	—	—	—
1910.....	98	11·7	—	—	30	5·4
1915.....	86	36·9	—	—	62	15·4
1920.....	91	21·3	—	—	29	10·9
1925.....	38	9·4	—	—	38	11·7
1930.....	69	12·8	3	0·3	52	14·3
1935.....	53	4·8	2	0·2	35	6·2
1939.....	31	5·3	7	0·7	31	5·3
1946.....	88	31	13	3·9	41	22·8
1947.....	99	32	34	8·5	40	16·5
1948.....	98	35	42	10·3	35	19·1

It is especially the large type of trawlers that are operating on the herring, but as the result of some experiments in 1948 many of the largest and most powerful herring luggers are now fitted out with both drift-nets and trawl, so that they are able to fish with either gear.

Moreover, since the war an inshore fishery has developed on spent herring off the Belgian and southern Dutch coast in which a great number of small vessels participate.

The drift-net fishing grounds extend from the Shetland Isles to the eastern part of the Channel. Drift-net catches of the majority of the luggers have been used in 1947 and 1948 for the drawing of herring charts. On these charts has been indicated the number of shots in each rectangle and the mean catch per shot. They show where and when the luggers have been fishing and what has been the catch in each locality.

As the charts for 1947 and for 1948 have been published in the *Annales Biologiques*, Vols. IV and V respectively, I need not give the details here.

For the herring trawl, details of the localities of the fishery and the size of the catches (with the exception of the fishery on spent herring) have been drawn in another series of herring charts, published in the same way in the *Annales Biologiques*.

From Table 1 it is evident that the total catches of herring (drift-net + trawl) have increased considerably (about 100%) as compared with the last decennia before the war.

It would be interesting to know if an equivalent increase of the catches has occurred in other countries fishing on the herring populations of the North Sea. Presumably, at least in some of them, this will be the case.

A very important problem that concerns both our biologists and ship owners is the question: can the productivity of the herring stocks which for many centuries has supplied abundant catches, stand the recent and still steadily increasing intensity of fishing?

As a warning we have before us the fatal course of the stocks of demersal fishes in the North Sea and

Table 2. Catch per shot of drift-net luggers in 1947 and 1948.

The first column in each month indicates the number of rectangles in which a catch of a certain number of kantjes per shot has been made, in the second column the product is given of the number of rectangles and the mean catch in these rectangles. A, number of rectangles; B, total in rectangles; M, average catch per rectangle.

Mean catch per rectangle per shot (in kantjes à 94 kg.)	May		June		July		August		Sept.		Oct.		Nov.		Dec.	
						1947										
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
5	17	85	20	100	44	220	36	180	12	60	8	40	1	5	—	—
20	47	940	32	640	78	1560	53	1060	20	400	15	300	3	60	11	220
40	24	960	37	1480	51	2040	41	1640	37	1480	13	520	5	200	9	360
60	11	660	8	480	12	720	16	960	22	1320	20	1200	7	420	—	—
80	—	—	4	320	6	480	8	640	12	960	18	1440	14	1120	—	—
100	3	300	2	200	1	100	6	600	7	700	7	700	9	900	—	—
120	—	—	3	360	2	240	2	240	6	720	14	1680	6	720	1	120
M	24·2		30·6		25·9		28·1		30·7		55·5		76·1		31·8	
						1948										
5	32	160	79	395	36	180	21	105	13	65	14	70	—	—	7	35
20	35	700	106	2120	84	1680	32	640	27	540	52	1040	2	40	10	200
40	8	320	9	360	38	1520	32	1280	42	1680	17	680	6	240	1	40
60	—	—	2	120	9	540	15	900	31	1860	20	1200	13	780	—	—
80	—	—	—	—	1	80	4	320	9	720	11	880	7	560	—	—
100	—	—	—	—	2	200	3	300	2	200	4	400	5	500	—	—
120	—	—	—	—	2	240	2	240	3	360	5	600	4	480	—	—
M	15·7		15·0		25·8		34·7		42·4		39·3		70·3		15·3	

it seems unreasonable to suppose that the productivity of a pelagic fish like the herring should be nearly unlimited.

The continuous increase in the total catches up to the year 1948 does not indicate definite signs of overfishing. The figures, however, concerning the catches per unit of effort in the last few years show a distinct decrease.

If we compare the catches per shot on the herring charts in 1947 and 1948, it is striking that the rectangles with large catches are less numerous in 1948 than in 1947.

As the charts for 1948 have not yet been issued at this moment[1]) and moreover in order to give these data a form which will make comparison easier, I have summed the number of rectangles in which catches of a certain size have been made (first column for each month in Table 2). In the second column the product is given of the number of rectangles and the mean number of kantjes (94 kg.) that has been calculated for this rectangle. From these figures a mean has been calculated by adding the mean numbers of kantjes caught in the different categories of rectangles and dividing them by the number of rectangles. From this table it is evident that the highest categories of catches (80, 100, 120 kantjes per shot) in 1947 have been made in 62, 35, and 34 rectangles, in 1948 these figures were 32, 16 and 16. Generally one may say, therefore, that the number of rectangles with abundant catches was about 2 × as high in 1947 as in 1948.

[1]) October 1949.

The mean catch per rectangle in 6 months was larger in 1947 than in 1948, mostly considerably larger; only in August and September was it larger in 1948.

The reason for this drop of the catches may be sought in a decrease in the density of the stocks of herring on the grounds fished by the Dutch luggers, but of course there are many factors that can influence the results of the drift-net fishery.

It is, therefore, interesting to have a look at the herring trawl landings. In Table 3 the catches of

Table 3. Catch of herring in kg. per one hour fishing by Dutch large trawlers.

Month	1946	1947	1948
July	—	309	336
August	—	899	620
September	1·839	877	675
October	970	968	553
November	—	771	301

herring by Dutch large trawlers per one hour fishing for 1948, 1947 and for 2 months of 1946 are given. These figures demonstrate very clearly how, since September and October 1946, the catches have been decreasing, and this despite the fact that new and more effective trawlers have been added to the fleet in 1947 and 1948.

At the moment of writing, little is known about the results of the fishery in 1949. It may be said, however, that the spring and summer fishery with drift-nets for matties has been still worse in 1949

than in 1948: landings up to July 1949 were about 94,000 kantjes as against 144,000 kantjes in 1948.

It is possible that the fishery in 1946 had profited from an accumulation of the stocks due to the inactivity of the fishery during the war. It is also possible that natural factors: fluctuations, wider spreading of the shoals, or absence from the habitual fishing grounds, have caused the decrease. But it is also acceptable that the fishing intensity has affected the stocks to such a degree that the catches of trawl herring per unit of effort in 1948 have dropped to about 50% of those in 1946.

If the supposition is true that the abundant fishery of 1946 was due to an accumulation of the stocks, then the decreased catches in 1947 and 1948 would provide the proof that the fishing during these years has had a considerable influence on the stock.

If such a considerable influence really exists, the question arises as to whether a continuation and extension of the modern fishing methods would lead to overfishing, and it seems that for safety we have to reckon with this possibility and to act accordingly.

This action should consist in the promoting of investigations that can be divided into 2 parts:

I. Statistical investigations in order to get an insight into the problem of what is the effect of the fishery on the stocks. These investigations will be complicated by the fact that the activity both of the trawl and the drift-net fisheries has to be considered. Continuation of the investigations on the relative abundance of year-classes is of pre-eminent value in this work.

II. Investigations that can contribute to the preventing of overfishing. English investigations have already shown the effect of the size of meshes of drift-nets on the size of the herring caught. These investigations should be extended; particularly knowledge is wanted as to the influence of the size of meshes on the composition and density of the stocks.

The same problem arises for the herring trawl.

It seems to me that it is not premature to begin these investigations now, for it will take a series of years to complete them. The statistical investigations especially will need time, as natural fluctuations of the stocks will often interfere with the results.

If we do not need knowledge of these matters at the moment, we shall need it in the future, for there is every reason to suppose that the fishery will expand up to the point at which overfishing will make the industry unprofitable.

7.

Observations on the Value of l_1 in Herring Investigations.

By

Henry Wood

Among the recommendations approved at the meeting of Herring Experts at Aberdeen in June 1946, No. 8 stated that steps should be taken to test the value of l_1, the calculated size at the end of the first growth period after the formation of the scales, in the identification of herring types.

Some types or groups of herring can be distinguished by the total number of vertebrae or by the number of K_2, the keeled scales which lie between the anus and the pelvic fins. There are, on the other hand, types such as the autumn spawners of the north-western North Sea and the late autumn and winter spawners of the Southern Bight, where counts of vertebrae or K_2 do not provide adequate distinctions.

One would expect that differences in spawning times could result in appreciable differences in the values of l_1, and if that were so this character would be not only a useful but a most convenient one to use. In this paper, after a preliminary survey, it is proposed to give attention to the herring of the Clyde Estuary with a view to getting some information on growth variations in a group of fish which use a known spawning ground and spawn within a limited period of the year.

Lea made a large number of growth calculations from scales collected by Dahl, published in *Publications de Circonstance* No. 53. Only a little of this material is used in this survey, the selection of samples being determined mainly by their geographical location, and for the same reason some data collected at the Marine Laboratory Aberdeen from the north-western North Sea have been added.

The number of growth data from the north-western North Sea is relatively small and should not be regarded as necessarily typical for this region.

The symbols used are those adopted by Lea, l_1, l_2 etc. representing the calculated lengths at the end of the first, second and subsequent growth periods after the appearance of scales, and t_1, t_2, etc. representing length increments. See Figure 1 and Table 1.

It will be seen by reference to Figure 1 and to the mean values in Table 1 that l_1 values in samples from northern Norway down as far as Vesterålen are less than in samples from Kristiansund and from the North Sea generally. We find, however, by consulting Lea's tables that the samples from northern Norway here represented were either sexually immature or contained a high proportion of immature fish, whereas in the case of the samples from Kristiansund and from the neighbourhood of the Viking Bank the majority or all of the fish were mature or maturing. Those facts compel one to use caution in assessing growth conditions on the north and west coasts of Norway, because the apparent differences in growth-rates may have been brought about by segregation of the quicker growing and earlier maturing individuals of the northern stock or population towards the south where their spawning places lie. This possibility is supported to some extent by the t or increment values. It is seen, for example, from Table 1 that the length increments in the fourth year in the samples from north and north-west Norway are greater than in those from any other grounds illustrated here, although one has to admit that growth in the fourth or any other year must be influenced to some extent by previous growth history and the size typical of the adult.

Examination of Figure 1 and Table 1 shows that on the credit side there is a reasonable possibility that l_1 values could be used as an aid in distinguishing the autumn spawning herring of the north-western North Sea from the Norwegian spring spawning herring and from the late autumn or winter spawning herring of the Southern Bight. But even this limited possibility must be accepted with caution. It is to be noted, for example, that in the data available there is no appreciable difference in size at the end of the first growth period after the assumption of scales

l_1 and t_4 Calculations From Scale Rings.

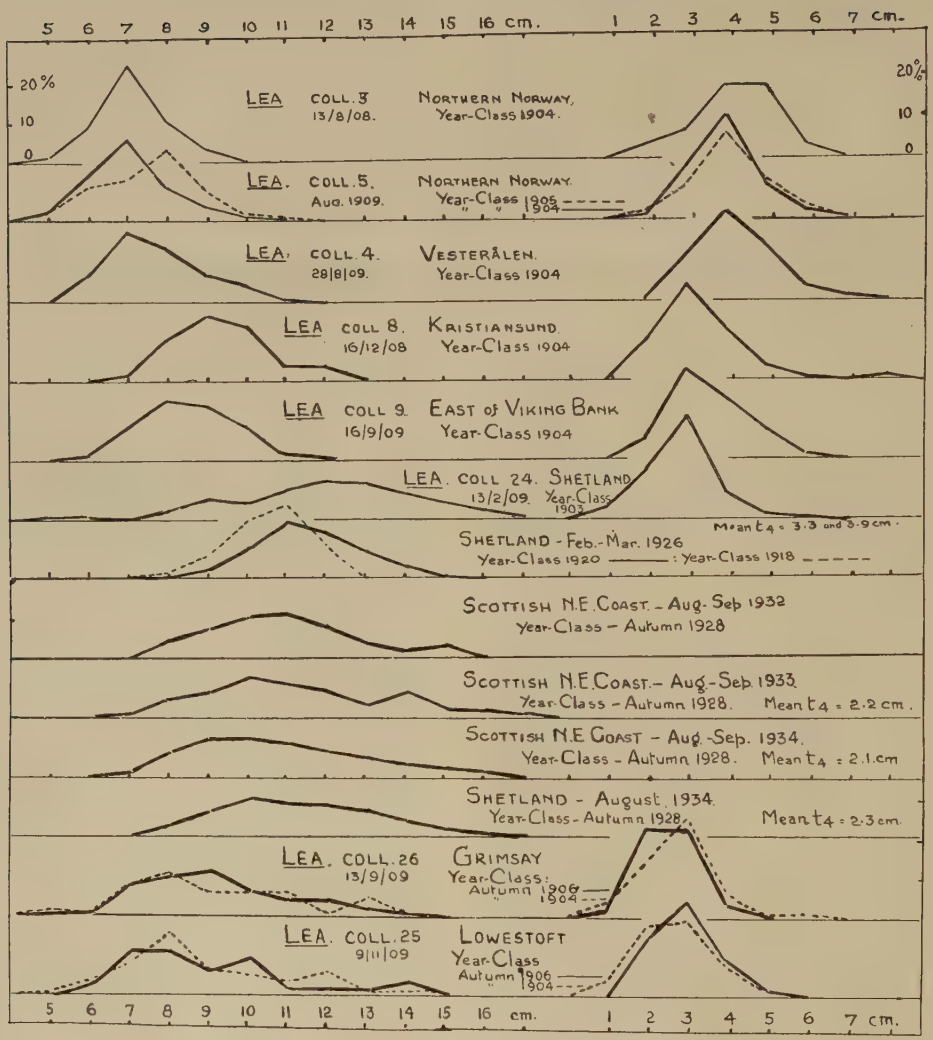

5 6 7 8 9 10 11 12 13 14 15 16 cm. 1 2 3 4 5 6 7 cm.
20%
10
0
LEA COLL. 3 13/8/08. NORTHERN NORWAY. Year-Class 1904.
LEA. COLL. 5. Aug. 1909. NORTHERN NORWAY. Year-Class 1905 ----- " " 1904 ———
LEA. COLL. 4. 28/8/09. VESTERÅLEN. Year-Class 1904
LEA COLL 8. 16/12/08 KRISTIANSUND. Year-Class 1904
LEA COLL 9. 16/9/09 EAST of VIKING BANK. Year-Class 1904
LEA. COLL 24. 13/2/09. SHETLAND. Year-Class 1903
Mean t_4 = 3.3 and 3.9 cm.
SHETLAND - Feb.-Mar. 1926
Year-Class 1920 ———: Year-Class 1918 - - - - -
SCOTTISH N.E. COAST. - Aug.-Sep 1932
Year-Class – Autumn 1928
SCOTTISH N.E. COAST.– Aug.-Sep 1933.
Year-Class – Autumn 1928. Mean t_4 = 2.2 cm.
SCOTTISH N.E COAST – Aug.-Sep. 1934.
Year-Class – Autumn 1928. Mean t_4 = 2.1 cm
SHETLAND – August 1934.
Year-Class – Autumn 1928. Mean t_4 = 2.3 cm.
LEA. COLL. 26 13/9/09 GRIMSAY
Year-Class: Autumn 1906 ——— " " 1904 - - -
LEA. COLL. 25 9/11/09 LOWESTOFT
Year-Class Autumn 1906 ——— " " 1904 - - -
5 6 7 8 9 10 11 12 13 14 15 16 cm. 1 2 3 4 5 6 7 cm.

Figure 1.

between the Shetland adult spring spawners and the autumn spawners of the north-western North Sea hatched out six or seven months earlier.

Incidentally, discussion of the differences in the l_1 values of the year-class autumn 1928 as sampled at Shetland and off Peterhead in 1934 may be introduced here as it involves again the question of segregation. Wood (1936) has shown that the immature herring in the commercial catches at Shetland are predominantly if not exclusively derived from spring spawning stock. Few autumn spawning herring are to be found on the Shetland grounds less than four years old, and nearly all the four-year-old fish give evidence of having spawned at three years. Three-year-old spawners, which are normally quick growing fish, are frequently numerous off the east and north-east coast of Scotland and it would appear that it is from these early spawning quick growing herring that the first recruits to the Shetland autumn spawning shoals are derived.

It is clear from Figure 1 and Table 1 that l_1 values by themselves can have only a limited application in the identification of herring types unless associated with some other character. Amongst the growth data available the most consistent values are associated with t_4, the length increment in the fourth year. The highest average t_4 values occur without exception in the Norwegian spring spawning herring, and those of the Shetland spring spawners are higher than those of the autumn spawners of the north-western North

Table 1. Mean Length and Length Increments (cm.) calculated from Scale Rings.

Details of Sample	Year-Class	l_1	l_2	l_3	l_4	l_5	l_6	l_7	t_1	t_2	t_3	t_4	t_5	t_6	t_7	No. of fish
Northern Norway	Spring															
Lea. Coll. 1. 10.8.07 ...	1904	7·2	12·8	17·5	—	—	—	—	7·2	5·7	4·7	—	—	—	—	54
Lea. Coll. 3. 13.8.08 ...	1904	7·1	12·3	16·0	20·2	—	—	—	7·1	5·3	3·6	4·2	—	—	—	58
Lea. Coll. 5. 8.09	1906	8·2	14·3	19·9	—	—	—	—	8·2	6·1	5·6	—	—	—	—	212
	1905	7·8	12·9	17·7	21·8	—	—	—	7·8	5·1	4·8	4·2	—	—	—	76
	1904	7·0	11·9	15·4	19·3	22·7	—	—	7·0	5·0	3·4	3·9	3·4	—	—	282
Vesterålen																
Lea. Coll. 4. 28.8.09 ...	1904	7·7	13·4	17·0	21·2	24·9	—	—	7·7	5·7	3·6	4·2	3·7	—	—	43
Kristiansund																
Lea. Coll. 8. 16.12.08 ..	1904	9·3	17·8	23·9	27·2	29·5	—	—	9·3	8·5	6·1	3·3	2·3	—	—	54
East of Viking Bank																
Lea. Coll. 9. 16.9.09 ...	1904	8·4	15·9	21·9	25·3	27·6	29·1	—	8·4	7·5	6·0	3·5	2·2	1·5	—	197
Shetland																
Lea. Coll. 24. 13.2.09 ..	1903	11·9	20·1	24·2	27·2	28·8	30·0	—	11·9	8·2	4·1	3·0	1·6	1·2	—	83
Shetland																
[1]) Feb.-Mar. 1926.....	1920	11·5	18·6	23·4	26·7	28·7	—	—	11·5	7·1	4·8	3·3	2·0	—	—	202
	1918	10·5	17·0	22·6	26·5	29·1	30·5	31·3	10·5	6·5	5·6	3·9	2·6	1·4	0·8	199
Scottish NE. Coast	Autumn															
[1]) Aug.-Sept. 1932.....	1928	11·0	18·6	22·8	—	—	—	—	11·0	7·6	4·2	—	—	—	—	251
Aug.-Sept. 1933.....	1928	11·3	19·0	23·0	25·2	—	—	—	11·3	7·7	4·0	2·2	—	—	—	258
[1]) Aug. 1934.....	1928	10·8	18·5	22·7	24·8	26·1	—	—	10·8	7·7	4·2	2·1	1·3	—	—	255
Shetland																
[1]) Aug. 1934	1928	11·4	19·2	23·4	25·7	27·0	—	—	11·4	7·8	4·2	2·3	1·3	—	—	283
Grimsby																
Lea. Coll. 26. 13.9.09 ..	1906	9·2	17·1	21·6	24·1[2])	—	—	—	9·2	7·9	4·5	2·5	—	—	—	141
	1905	8·5	16·1	21·0	23·4	25·0[2])	—	—	8·5	7·6	4·9	2·4	1·6	—	—	206
	1904	9·1	16·1	20·5	23·3	24·9	26·1[2])	—	9·1	7·0	4·4	2·8	1·6	1·2	—	67
Lowestoft																
Lea. Coll. 25. 9.11.09 ..	1906	8·8	16·5	21·3	24·3[2])	—	—	—	8·8	7·7	4·8	3·0	—	—	—	31
	1905	9·0	16·8	21·4	23·9	25·4[2])	—	—	9·0	7·8	4·6	2·5	1·5	—	—	102
	1904	8·9	16·3	20·9	23·7	25·2	26·4[2])	—	8·9	7·4	4·6	2·8	1·5	1·2	—	108

[1]) New Data. [2]) Mean Size at Capture.

Sea and those of the late autumn and winter spawners of the Southern Bight.

Growth Data from the Herring of the Clyde Estuary.

During the investigation of the Clyde Herring extending from 1930 to 1939, a very large number of growth calculations has been made and it is thought that the results of this work will be of some interest to those engaged in herring research and of some value in the question at issue.

The samples used were caught exclusively by ring-net. Length measurements were made to the nearest mm.; a sample of scales was taken from each fish and from these two were selected and mounted permanently; maturities were noted according to the Hjort scale and counts were made of vertebrae and K_2 as frequently as possible.

Spawning in the Clyde Estuary is usually completed at the end of March or early April. Evidence of new growth on the scales is apparent in April. Accordingly in this survey 1st April is accepted as the beginning of the biological year for the Clyde herring and data are arranged according to this calender.

Composition of the Clyde Herring Stock.

Fulton, Ewart, Brook and Williamson give records which indicate the occurrence of autumn spawners in the Clyde estuary, but it is difficult to discover from their work whether autumn spawners were numerous or not. It would appear from their writings that autumn spawners were more numerous than now, but it is known that much of their material was caught by drift-nets, which would catch only the larger herring. Drift-nets are no longer used in the Clyde and the ring net which is now the chief means of capture is much less selective in its captures than the relatively larger mesh drift-nets previously used.

Marshall, Nicholls, and Orr in 1935 caught by a shore seine considerable numbers of "0" group herring which formed two very distinct size-groups. They were able to establish by vertebral counts that the smaller group originated from spring spawning stock

Table 2. **Clyde Herring.**

Maturities of Samples from Upper, Lower and Outer Estuary. Percentages.

1930—1939.

Part of Estuary	Year	Period	I	II	III	IV	V	VI	VII	No. of Fish
Lower	1930	March	62·9	19·8	11·6	3·1	—	0·3	2·3	793
Outer	1930	February	—	—	—	1·8	17·3	77·2	3·6	221
Lower	1930	Aug.-Sept.	71·7	16·9	10·6	0·8	—	—	—	3,493
Lower	1930	Oct.-Nov.	23·7	28·7	43·4	4·2	—	—	—	1,680
Upper	1930/31	Dec.-Jan.	28·0	17·6	39·0	14·8	0·5	—	0·2	1,026
Upper	1931	January	2·6	5·4	31·6	58·1	2·3	—	—	430
Outer	1931	Feb.-Mar.	—	—	0·2	1·8	2·2	93·4	2·4	697
Lower	1931	Aug.-Sept.	71·0	14·7	13·0	1·2	—	0·1	—	1,886
Lower	1931	Oct.-Nov.	9·3	41·7	44·9	4·0	—	—	—	833
Lower	1932	February	9·4	1·3	23·6	57·0	8·4	0·3	—	381
Outer	1932	Feb.-Mar.	—	—	—	0·7	2·1	96·8	0·4	565
Lower	1932	September	21·1	50·1	26·6	2·2	—	—	—	327
Upper	1932	November	11·2	3·2	44·7	38·2	2·6	—	—	311
Lower	1932	Oct.-Nov.	7·6	9·0	55·4	26·7	1·3	—	—	590
Outer	1933	Feb.-Mar.	—	—	0·4	2·5	6·6	88·9	1·5	823
Lower	1933	Aug.-Sept.	69·8	20·5	9·3	0·3	—	—	0·1	1,722
Upper	1933	November	27·3	13·4	49·8	9·4	—	—	—	498
Lower	1934	January	2·1	5·8	54·8	36·0	1·3	—	—	377
Outer	1934	Feb.-Mar.	—	0·1	4·1	24·3	7·8	62·1	1·7	1,207
Lower	1934	September	5·7	79·4	14·5	0·4	—	—	—	282
Upper	1934	October	3·5	19·7	65·8	11·0	—	—	—	289
Lower	1935	February	—	—	9·0	63·1	20·2	7·7	—	233
Outer	1935	Feb.-Mar.	—	—	0·5	2·2	3·0	94·1	0·2	798
Lower	1935	September	42·3	38·2	16·0	3·6	—	—	—	364
Upper	1936	January	11·9	6·6	32·3	49·2	—	—	—	303
Lower	1936	February	0·9	0·9	43·7	51·0	3·0	0·6	—	334
Outer	1936	Feb.-Mar.	0·2	0·2	0·3	5·2	10·0	83·6	0·5	799
Lower	1936	August	33·2	52·0	13·3	1·5	—	—	—	262
Lower	1937	January	21·1	11·6	17·7	45·8	3·1	—	0·7	293
Outer	1937	February	—	—	—	4·3	6·0	89·3	0·4	501
Lower	1938	January	6·4	12·9	41·4	36·4	3·0	—	—	284
Outer	1938	Feb.-Mar.	0·4	—	0·3	0·6	4·2	94·0	0·6	1,117
Lower	1938	August	10·1	56·6	31·8	1·5	—	—	—	267
Lower	1938	October	5·7	18·8	62·1	13·4	—	—	—	261
Outer	1939	March	1·6	0·3	—	0·1	0·1	96·1	1·7	770
Lower	1939	November	24·8	12·8	38·5	22·0	1·7	—	0·2	510

The maturities of samples caught between April and July have not been included in the table, but they are avaiable at the Marine Laboratory if required.

and the larger from autumn spawning stock. MARSHALL and ORR, however, did not ascribe the latter progeny to a local stock but indicated the probability of their being derived from Manx autumn spawners.

Maturities.

Relatively few herring in the Clyde samples examined since 1930 had reached or had developed before August beyond stage III of the maturity scale and accordingly only samples caught between 1st August and 31st March have been used in the preparation of Table 2.

It has been found convenient to divide the estuary into three zones: (1) the upper estuary, which includes all waters north of the Cumbraes: (2) the lower estuary which extends southwards from the Cumbraes and embraces the channels on the east and west coasts of Arran and (3) the outer estuary or spawning area which extends seawards from the south coast of Arran and includes Ballantrae Bank.

The maturities given in Table 2 represent in many cases means for periods of two months. When only one sample has been available it is given according to the month of capture.

Clyde Herring.

Maturities of Samples from the Upper, Lower, and Outer Estuary. 1930—1931.

A significant feature of Table 2 is the paucity of herring which have developed beyond stage IV in the period between 1st August and 31st December. A trace of ripe herring, stage VI, is recorded from the lower estuary in the period August—September, 1931, and traces of spents are noted from the upper estuary in period December—January, 1930—31 and from the lower estuary in the period August—September 1933 and in November 1939. One would infer from the data in Table 2 that autumn spawning herring were not numerous in the Clyde Estuary between 1930 and 1939.

In a reference to autumn spawning herring, FULTON[1]) states that "Although it is known that some herrings spawn in Loch Fyne in July and August and later in the year, it is evident that the great bulk of the shoals leave the loch and spawn outside, probably to a large extent in comparatively deep water in Kilbrennan Sound".

The sea floor in Kilbrennan Sound is covered for the most part with a thick layer of soft mud which renders it most unsuitable ground for herring spawn.

WILLIAMSON made a large number of measurements of ovaries and ova from Clyde herring and, while he states that the majority of Clyde herring are winter spawners, he adds that a considerable proportion of them are autumn spawners. In spite of these statements one notes the paucity of spent fish in his autumn samples.

BROOK and EWART, on the other hand, successfully carried out fertilization experiments with ripe ova from herring caught in Kilbrennan Sound in September 1885.

The occurrence of autumn spawning herring in the Clyde Estuary is beyond doubt but, while autumn spawners may have been at one time numerous in the Clyde, the records collected between 1930 and 1939 indicate that adult autumn spawners are now very scarce. There is, however, the possibility that adolescent autumn spawners may frequent the estuary and go elsewhere to spawn. If such is the case, certainly few return as spents. Fortunately, a large amount of "race" data has been collected since 1931 and these remove all doubt as to the composition of the adolescent herring of the Clyde Estuary.

"Race" Characters of the Clyde Herring.

The starting point in the "Race" analysis of any stock or community of herring in the Scottish investigations has been to determine the characters of the more important spawning communities and thus to establish a standard for comparison.

The main spring spawning season in the neighbourhood of the Clyde Estuary extends from the beginning of February until the end of March. There has been little or no evidence in recent years of autumn spawning on an appreciable scale either within or near the estuary. Nevertheless, the autumn spawning grounds near the Isle of Man and off the north coast of Ireland are not far distant. Counts have been

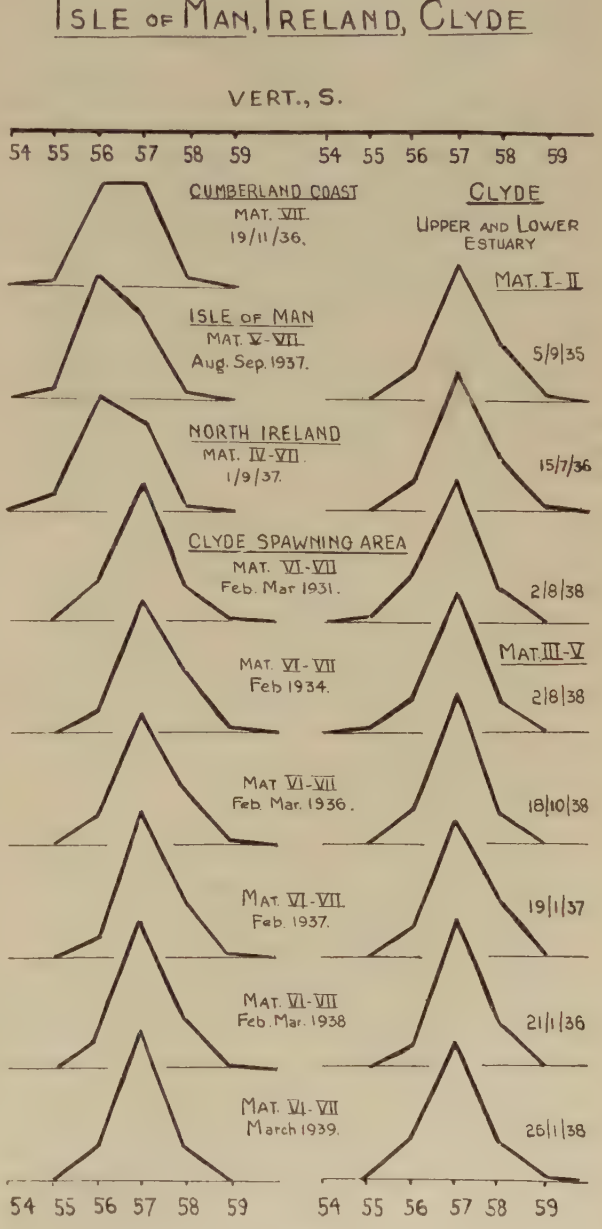


Figure 2.

[1]) Eighteenth Ann. Rep. Fish. Board Scotland, 1900, p. 253.

made of the vertebrae and the keeled scales of samples of Manx and North Ireland autumn spawners and of spring spawners from the spawning grounds off the south coast of Arran, and with these as standards, it is hoped to assign the immature and adolescent herring of the Clyde Estuary to their appropriate group or type.

It has been the practice in the Scottish investigations to use both vertebral and K_2 counts in this work, but in the present analysis only the former have been used. Results are summarised in Figure 2, a series of graphs illustrating autumn spawners from the Isle of Man and North Ireland, spring spawners from the outer part of the Clyde Estuary and finally the adolescent and maturing herring from the inner and lower zones of the estuary.

Only one of the samples illustrated contained less than 200 fish.

In a sample of fish caught in Kilbrennan Sound on 15th July 1936, nine herring had developed to maturity stages III and IV. Counts of the vertebrae and K_2 gave the following results:—

Vert. S.			K_2			
56	57	58	13	14	15	16
4	4	1	1	1	5	2

These figures suggest rather strongly that these nine fish were autumn spawners.

The remainder of the results illustrated in Figure 2 show very definitely that if the estuarine stock is not exclusively spring spawning it is certainly very predominantly so. This conclusion is supported by age analysis of the estuarine adolescents and the adult spawners.

Age Analysis of Clyde Herring.

It is evident from Figure 3 that the year-classes which predominated among the adolescents within the estuary became prominent and frequently predominated at three years of age among the spawners. In fact, the age composition of the spawners assumes very closely the same pattern as that of the estuarine stock, except that no year-class remains conspicuous among the estuarine herring after the fourth year. It will be noted, however, that a year-class may be conspicuous among the spawners for several years after it has virtually ceased to exist within the estuary.

It becomes clear that the spawning shoals are recruited to a very great extent from the estuarine population and that at each spawning season some of the herring that have spawned in a previous year return to spawn again. There is a notable consistency in the vertebral counts and in the sequence of prominent age-groups in the herring of the Clyde Estuary which renders them very appropriate for a study of l_1 values.

l_1 Calculations of Clyde Herring.

Age and maturity data have shown that the Clyde stock until the winter months consists very largely

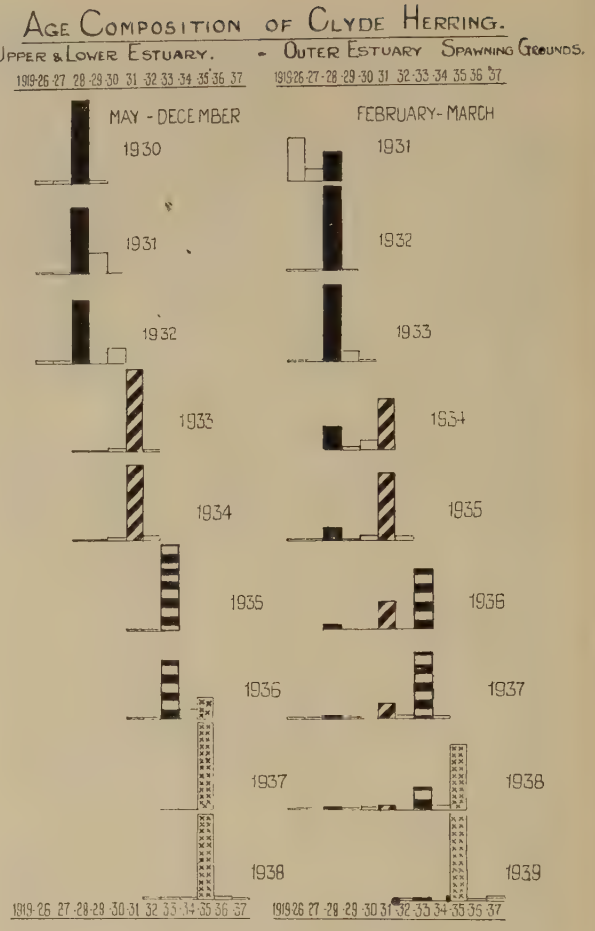


Figure 3.

if not exclusively of adolescent herring. Some mature for the first time at the end of their third year. As a rule, the majority have spawned at the end of their fourth year, but on occasions it would appear that some may not mature until their fifth year; see age composition in 1932. The proportions obviously vary from year-class to year-class and whatever may be the deciding factors one cannot but believe that growth conditions, not necessarily in the first year but in the first three or four years, have an important effect in determining the age at which the first spawning takes place.

In the l_1 calculations in Figure 4 comparison is made, when adequate material is available, between the herring of the inner and lower estuary and the herring caught as spawners in the outer estuary during the same biological year. Figure 4 also makes possible a comparison of growth in the first year of four different year-classes originating in 1928, 1931, 1933 and 1935 respectively, all of which were very successful broods.

All samples illustrated contained over 200 fish.

Several noteworthy features are apparent in Figure

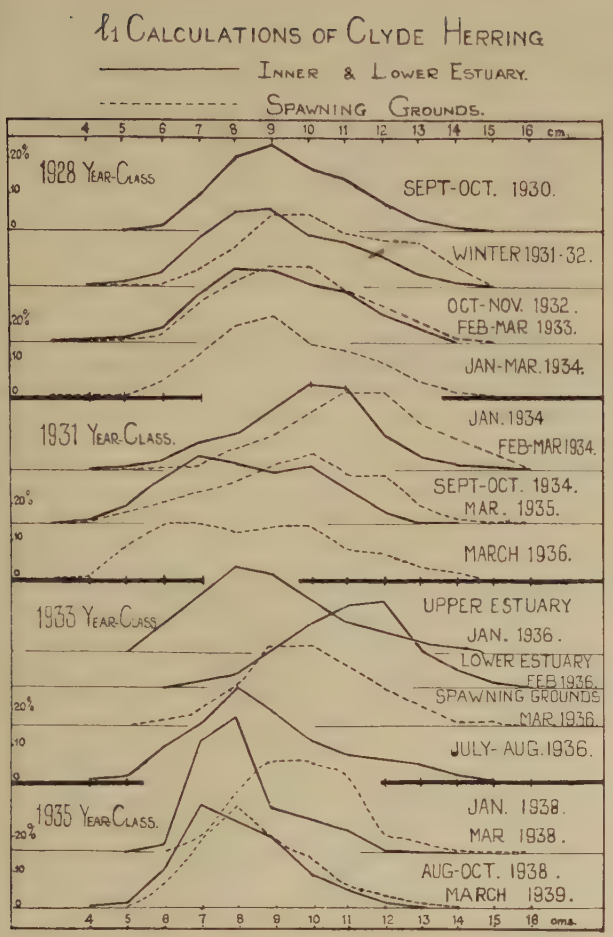


Figure 4.

4. Substantial differences, for example are apparent in the mean and modal values of l_1 of fish of the same age but belonging to different year-classes. As might be expected there is evidence of considerable variation in growth from year to year. Then it may be noted that l_1 values for spawners are with one exception—the year-class 1933 as represented in the samples caught in February and March, 1936—higher than those of the same year-class caught within the upper and lower estuary during the same biological year.

Another feature is the tendency towards a decrease in l_1 values amongst spawners of the same year-class from the third to the fourth and fifth years.

In short in the Clyde herring, which is probably as homogeneous with regard to origin and spawning habits as any group of herrings, and the great majority of which as far as can be ascertained spend the first 3 years of their life within the estuary, show such a wide range in the first year's growth that it would appear impossible to find a value which could be accepted as typical for this community of herrings.

Practically all the fish landed from the south coast of Arran and from Ballantrae Bank are caught in February and March and are spawners. Completely spent fish occur in catches in very small numbers or not at all. Samples from the estuary in April and May sometimes include a few fish which have been identified as recovering spents, but their proportions are invariably insignificantly small. There is thus no doubt that the spawners which have matured within the estuary leave the estuary to concentrate on the spawning grounds and in turn leave the spawning grounds for a more open sea or oceanic habitat and do not reappear until the approach of the subsequent spawning season. This is confirmed very convincingly by the age analysis in Figure 3. Such being the case a decrease in l_1 values must inevitably result from the dispersal of the quicker growing fish.

Decrease in the calculated sizes at the earlier years with increase in age is a feature common to many and probably to all herring types, and there has been a tendency for scientists to assume that as a fish becomes older the growth of fish and its scales become disproportionate. This may be so, but the material from the Clyde shows that a similar result is obtained by the segregation and dispersal from the main body of a year-class of the quick growing and early spawning fish, whereby successive remnants of slower growing and later spawning fish are left. There is also little doubt that this result is promoted to some extent by the earlier elimination by fishing of the quick growers.

The material collected in January, February and March 1936 is of special interest as it suggests the possibility of unsuspected complications. In this case a sample caught in the lower estuary in February had an appreciably higher modal l_1 value than a sample of spawners caught in March and still higher than a sample caught in the upper estuary in January, (see Figure 4). The maturities of the 1933 year-class in the three samples were the following:—

Maturity Stage	Upper Estuary	Lower Estuary	Spawning Ground
		1936	
	Jan.	Febr.	March
I	11·1	0·8	0·4
II	6·7	1·2	0·2
III	32·9	55·9	0·2
IV	49·3	41·4	0·2
V	—	—	—
VI	—	0·8	98·0
VIII	—	—	0·9
No. of fish	298	256	444

The differences in the l_1 values of the samples from the upper and lower estuary are not associated with any substantial differences in their maturities. There is thus the possibility that our problem may be complicated by differences in growth conditions throughout the main channel of the estuary and its many branching lochs. Dannevig (1949) has found some evidence of this in a study of young codfishes in some Norwegian Fjords. The important fact is that with such variations in the value of l_1 in the same and in different year-classes as are revealed in Figure 4,

Table 3. **Clyde Herring.**

Mean Values of t_4 — Size Increment in Fourth Year.

Year-Class	Adolescents from Estuary				Adults from Spawning Grounds		
	in ... Year	Time of Capture	cm.	No. of Fish	Time of Capture	cm.	No. of Fish
1928	4th	Winter	3·5	743	February	3·5	250
1928	5th	Oct.-Nov.	3·4	396	Feb.-March	3·4	656
1928	6th	—	—	0	Jan.-March	3·4	369
1931	4th	Sept.-Oct.	3·2	461	March	3·6	329
1931	5th	—	—	0	—	3·4	211
1933	4th	July-Aug.	2·5	302	—	—	—
1935	4th	Aug-Oct.	3·2	476	March	3·1	489

one cannot readily accept this character as a reliable means of identifying herring types.

Growth in the Fourth Year.

In the preparation of the Scottish growth data results were not tabulated for each individual fish and for the present mean values given in Table 3 must suffice.

The mean size increments in the fourth year are remarkably consistent. Apart from the material representing the 1933 year-class in its fourth year which was obtained in July and August, when the growth for the year is hardly likely to have been completed, the mean increment in the fourth year ranges from 3·1 to 3·6 cm. These values are lower generally than in the Norwegian herring examined by Lea. On the other hand they are appreciably higher than those found in samples of autumn spawners from the north-western North Sea and in the samples of late autumn or winter spawners from the Lowestoft and Grimsby grounds.

It was already apparent in Table 1 that a good growth increment in the fourth year is characteristic of Norwegian herring and of the herring which spawn in spring at Shetland. The same feature is apparent in the Clyde herring, and although no relevant data are available at the moment it is probably true also for the spring spawners of the Scottish west coast generally.

This brief analysis shows that it would be difficult to determine a value for l_1 which could be regarded as typical for any biological group or type of herring. The l_1 values in samples of Norwegian herring and of adult Shetland spring spawners have had in most cases a fairly normal frequency distribution. The same is generally true for the Clyde herring provided that one is dealing with herring of a given age within the same year-class, and using material representative either of the estuarine population or of the spawners.

The l_1 values of the autumn spawners from the north-western North Sea and of the later spawners of the East Anglian grounds have a wide frequency distribution and from the latter grounds the distribution according to Hodgson's data (1929) may be often bimodal or even trimodal. It has never been established whether any autumn hatched progeny have scales before their first winter, which might account for the wide range in the frequency distribution. It seems most improbable, and certainly there has been no direct evidence of such an occurrence in Scottish waters.

Furthermore in considering North Sea herring types one might expect additional growth variations, at least during the early years, to result from the different and varying conditions under which the adolescents are reared. There is good evidence, for example, that the distribution of the progeny produced on the Scottish east coast grounds in autumn extends from the Moray Firth to the Dogger Bank and perhaps even to the Danish coast. In due course the adult shoals of the north-western North Sea are recruited by herring in their third, fourth or even fifth year, and these recruits, drawn from nursery grounds which lie far apart, are likely to show greater variations in growth—and possibly in the definition of the winter rings—than progeny reared in more circumscribed grounds.

Although l_1 can sometimes have a useful though limited application in the recognition of herring types it can never have the validity of counts of vertebrae or K_2. There is obviously scope for further investigation but from the data available it is thought that the usefulness of l_1 would be increased appreciably if it were associated with t_4, the length increment in the fourth year.

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8.

Spotting Shoals with the Recording Echo Sounder.

By

William C. Hodgson

Historical Survey.

The first echo sounder to be installed in a fishing vessel was of the sonic type, i. e., one which used sound waves of low and audible frequency. This machine, which consisted of an electric hammer for producing the impulse and a hydrophone for receiving it, was fitted to a Hull steam trawler, and it was found to give accurate soundings to a depth of 270 fathoms. This was in 1928.

In 1930, the piezo-quartz ultra-sonic oscillator, based on the Langevin-Florisson principle, was introduced by the Marconi Co. in the form of a visual depth-recorder, the depth being shown by a flashing light on the scale. By 1935, some hundreds of vessels from Hull and Grimsby were fitted with the Marconi 424 instrument.

In 1933, the first recording instrument used in fishing was installed in the steam trawler "Glen Kidston" by Henry Hughes and Sons, (later known as Marine Instruments, Ltd.). This machine used the magneto-striction ultra-sonic oscillator and the depth was recorded electrolytically on a roll of paper. The first cruise from Hull to Bergen was an historic one, for the skipper was able to produce a continuous trace of the sea-bed on paper to the scale of 70 fm. to 5 inches of paper.

The advantages of such a system were at once obvious, for the skipper need no longer rely on his memory after watching the flashing light. Instead, he now had a paper record to which he could refer at leisure.

In 1935, Oscar Sund, using this type of machine on the Norwegian coast, made the first identified record of fish—cod—on the Lofoten grounds, and in the following year he was successful in producing records of herring shoals. The success of these experiments firmly established the recorder in the Norwegian fisheries for cod, herring and brisling.

In 1937, Runnström used the recorder to study the distribution of herrings on the coast of Norway west of Haugesund, and in 1942, Tester, using a Husun M.S. III recorder assisted the purse-seiners in the Vancouver district by spotting the shoals for the fishing fleet.

In 1946, Renou and Tchernia carried out experiments on the French coast with an American type N.J.3 recorder, and they were successful in obtaining good echoes of herrings, sprat, pilchards and tunny off the Brittany coast and in the English Channel.

Hodgson and Richardson, in 1947—8 used the M.S.XII recorder made by Marine Instruments Ltd. to locate pilchard shoals in Cornish waters and they showed that the instrument was capable of replacing the old "feeling-wire" method of locating shoals in the ring-net fishery.

Commercial Use of the Recorder.

Since the war, there has been a great increase in the use of the sounder for shoal-locating and both drifters and ring-netters are now beginning to rely on the information given by the recorder before shooting the nets. With the ring-netters, the information is more positive than with the drifters, because, once the shoal has been located, the net can be shot around it, but the drifter's problem is much more complicated.

The comparative slowness of setting the drift-nets in position in relation to wind and tide, makes it very difficult for a skipper to keep in touch with a shoal once it has been located, but the sounder does help him to get into an area where herrings exist, which is an advantage over the old 'hit-or-miss' method of choosing a berth by the appearance of the water or other signs.

One very important use of the sounder, so far as drifters are concerned, is in finding the exact depth at which the fish are swimming. In the North Sea, the nets are about 7 fm. in depth and they are suspended from the buoys by ropes which are usually 2 fm. in length, which means that the greatest depth reached

by the nets is 9 fm. Now, in many parts of the North Sea it has been found that the herrings will rise at night to within about ten or fifteen fathoms of the surface, which means that the drift-nets cannot possibly catch the fish unless the buoy-ropes are lengthened.

Most modern sounders are fitted with time indicators which show minute or half-minute intervals on the paper records, so that, if a skipper knows the speed of his ship, he can easily calculate the extent of a shoal and also estimate the catch he is likely to get from it.

Scientific Use of the Sounder.

The sounder is a useful instrument with which to study the behaviour of fish shoals in relation to wind, tide, and light, for it is possible to make a continuous record of the depth at which a shoal is swimming when under the influence of these factors.

In Cornwall, experiments were carried out on the effect of using a strong searchlight on the pilchard shoals, and it was found that as soon as the light was switched on, there was an immediate shock-reaction which caused them to descend in the water for a few seconds, after which they rose to the surface under the influence of the light. When the light was switched off, the fish at once fell to a lower level, but they rose again as soon as the light was restored.

The diurnal migration of sprats has also been studied in the Thames Estuary. Here, continuous records showed that the fish were at the bottom during daylight, but after sun-set they gradually rose to the surface. At dawn, again, they would sink to the deeper water.

It was also found that the sprats were packed together in dense shoals during the flowing tide, and also during the ebbing tide, but at the period of slack-water, the shoals dispersed so much that it was difficult to obtain echoes from them.

Some of the habits of pilchard shoals have also been observed by means of the sounder. For example, in September, it was found that the fish were massed together in dense shoals on the sea-bed by day, and at sun-set they rose to the surface and then scattered horizontally. After this scattering, no echoes were received from the fish but their presence was proved by the 'feeling-wire' and also by the fact that drifters were catching them with their surface nets.

Classifications of Echoes.

One of the most outstanding discoveries in connexion with the use of the sounder is the fact that certain species of fish can actually be identified by the type of echo recorded on the paper trace.

During the course of the work, a collection of traces has been made of different fish, all of which have been identified either by catching them in nets or by catching them on various forms of hand-lines, and the following is an outline of the results of these observations.

Herrings and Pilchards. Both of these clupeoids give clear echoes, even when the concentrations are very light. In large masses they are easily distinguishable from each other, for the edge of the herring trace is always diffuse as though it had been shaded with a pencil, while the pilchard trace is dense and the edge appears as though it had been painted with Indian ink.

Small sprats show a cloudy trace, diffuse like the herrings, and dense shoals of adult sprats usually have peculiar comet-like formation scattered throughout the trace. This has been found in both the North Sea and the Norwegian sprat shoals.

Gadoid Fishes, cod, coalfish and pollack all give a trace which seems to be characteristic of these gadoids. They are shown on the records as a series of 'specks' instead of dense shaded traces such as are produced by the clupeoid fishes.

Mackerel traces are again unlike any other. These fish produce a striated trace which has a peculiar 'ribbed' appearance irrespective of the density of the shoal.

As it is impossible to describe these different traces verbally, photographs of the classified records were shown at the herring meeting in Edinburgh, and members were able to study them closely.

9.

Herring Tagging.

By

Árni Friðriksson

When, in 1935, I became convinced of the interrelationship of the herring caught off the north coast of Iceland during the summer, and the large spring spawning herring of Norway, I thought it desirable to make a further study into this question by means of marking experiments. The first difficulty was, that none of the marking methods which had been applied in Europe seemed to be practicable when dealing with Icelandic herring. This was partly owing to the supposed delicateness of this fish, partly to mass capture and partly to the mass treatment in factories after capture which make it impossible to examine individual fish. On the west coast of America scientists had, at this time, developed a unique marking method for herring and sardines, which was successfully applied and gave the most astonishing results. This method, as is well known, is based on magnetic internal tags, which can be collected by magnets in the factories. During my stay in the United States in 1944, I used the opportunity to make a study of this question and to speak with some of the people who had been in charge of the work. Ten thousand herring tags were obtained but owing to war conditions the tagging had to be postponed until a later date. In the years 1945 and 1946 the plan was discussed with Mr. Einar Lea and in 1947 with the Norwegian director of fisheries, Mr. Brynjelsen. These preparatory discussions resulted in Mr. Lea and I meeting in Oslo in the beginning of May 1947 in order to make preliminary plans for an Icelandic-Norwegian herring tagging scheme. We agreed to adopt the American method in a somewhat modified form, owing to the special conditions in our waters, especially the open waters off Iceland. The meeting resulted in a memorandum, in which the tagging experiments, which, in their first stage, should cover several seasons, were highly recommended, and it was proposed to start the experiment in Icelandic waters in July or August of that year. As a specially constructed boat, to be used for the operations, could not be finished in time to start tagging that summer, only some preparatory observations were made in Iceland by me and Mr. Åsen, who has since that time been in charge of the work on behalf of Norway. Experiments on the efficiency of the magnets in the factories at Siglufjord led to the conclusion that these had to be altered to obtain the desired result. In addition, detailed observations were made on the handling of the herring during the tagging, on the position, size and depth of the cut etc. for the insertion of the mark. We came to the conclusion that the cut should be made by a small scalpel, parallel to a myomere, in order to avoid the cutting over of veins or bones, at the distal end of the right abdominal fin one scale and a half over the keel. One or two scales had to be removed first, and the instruments and the tag had to be disinfected each time before use. Experiments for the study of the vitality of tagged herrings were also arranged. The herrings were kept in wooden boxes, containing about a ton of sea water each, on board a vessel, under rather bad conditions. These experiments showed that the rate of mortality in the tagged herring was about 5% higher than in those not marked, and that some of the herrings—about 5%—were able to shake off the tag. Before Mr. Åsen's departure from Iceland a report was made on the work done and it was recommended by us to commence tagging during the next herring season in Norway.

During early spring in 1948 all the Icelandic herring meal and oil factories were inspected to find out the efficiency of the magnets. New magnets were provided where necessary and alterations were made when needed. In March that year, the first tagging experiments were carried out in Norwegian waters by Mr. Åsen and myself, and a report was made on the experience obtained during the work. 6018 tagged herrings were liberated in Norway during the season, and 7475 herrings were also released off the north coast of Iceland during August of the same year. The taggings were continued in Norway during the winter, when 8261 herrings were liberated, but un-

fortunately we were not able to make any tagging in Iceland last summer (1949). Altogether, 21,754 tagged herrings have thus been liberated at Norway and Iceland. We hope that this will be the beginning of a large-scale experiment and that the Icelandic part of the programme can be carried out in a satisfactory way in the years to come. I should like to point out that the conditions for tagging herring in Icelandic waters are extremely bad, on account of the lack of sheltered places and the prevailing rough weather conditions.

There is no doubt, that the marking of fish represents one of the most effective ways of coming to a conclusion on facts of vital importance for the fishing trade such as migrations of the species, rate of mortality, effect of fishing etc. As regards the herring, we are in urgent need of answers to the following questions.

1) Can the herring stand the treatment during the marking and can we hope to get sufficient returns by our methods to justify the vast amount of work and money spent on the project? This question I will answer in the affirmative. We are in possession of sufficient evidence to prove that the herring, when properly treated, can stand, at least this kind of marking, quite as well as other species of fishes, and the relatively large returns are most promising.

2) Long-distance migrations of individuals in a given tribe of herring.

3) Intermixing of more or less local tribes which we think are different, or perhaps non-intermixing of populations which we consider to be identical.

4) The rate of mortality in the tribes, especially owing to fishing operations, the knowledge of which will lead to the understanding of the resistance of the stock against fishing, so as to give an idea if a species is over-fished or not, and make it possible to estimate the optimum catch.

The herring marking scheme carried out in Norway and Iceland, has just commenced and can not be expected to give any final answer to important questions for the time being. But we have already had sufficient returns to enable us to say something about the results. Of the herrings, tagged in Norway in 1948, we have had nine returns in all, four being taken in Norway in 1948, a few weeks or even days after the tagging, four being found there in 1949, and one at Iceland this summer (1949). This last herring had been marked with the tag bearing the serial number B 10, at Breivik, Vestre Bolen, near Haugesund on 19. March 1948 and was caught near Langanes, North Iceland on 12. August 1949. There is another tag from Norway of 1948, which has a peculiar history, having been returned by a German housewife from a herring bought on the market in Essen, Germany. This was an A 2 tag and the first return we got. From the marking experiment which was carried out in Norway last winter only two returns have been reported so far. Thus we have 11 records of Norwegian tagged herring, 10 of which have come from Norway (including the German record) and one from Iceland.

As already pointed out we have only made one tagging experiment in Icelandic waters, which was carried out in 1948, when 7475 herrings were tagged. I am happy to say that we have got relatively many returns, 61 in all, 21 being caught at Iceland last summer (1948), 39 this summer and one in Norway last winter. Probably some additional records from this season can be expected when the factories close down later this year.

Besides the very important information on the long-distance migrations of the herring, the tagging experiments have already yielded some other valuable contributions to our knowledge of the herring. As already pointed out they have shown that the herring is quite capable of carrying its tag, thus indicating that the taggings have been successful. From 60 Icelandic returns, one herring had spent 4 days in the sea since liberation, one had spent 5 days, four 7 days, one 8 days, four 9 days, two 12 days, two 13 days, three 14 days, one 17 days, and one 19 days. The herring which was caught in Norway had spent 172 days in the sea and 39 herrings which were marked at Iceland last year and re-caught this year had all spent about a year in the ocean. Finally the herring, marked at Norway in 1948 and fished at Iceland last summer had spent one year, four months and twenty-four days in the sea.

Among the questions concerning the biology of the herring is whether the herring shoals should be regarded as more or less permanent units or if the shoals are broken up from time to time and the fractions combined in new shoals later on. Our experiment has clearly shown, that the latter proposition is right. Let us, as an example, take 505 herrings, which were tagged and liberated together, at Iceland on 22. August 1948. Five of these herrings have now been returned, one at Siglufjord at the middle of the north coast about 28. August 1948, another in Raufarhøfn at the eastern part of the north coast on 30. August 1948, the third on 4. September, at the same place, the fourth in Norway on 9. Februar 1949 and the fifth in Raufarhøfn, Iceland, 28. August 1949.

Finally I should like to remark on the occurrence of the herring off the north coast of Iceland during the summer of 1948. It is a part of my theory on the biology of the north coast herring, that only the major and vital part of the stock migrates to Norway in order to spawn, whereas a relatively small number of old herring, which do not spawn any more, or at least not annually, will remain in Icelandic waters until at least another year. Further I have tried to explain that the failure of the north coast fishing during recent years, may be due to the fact that the main part of the stock coming from Norway is situated further east than usual, owing to the influence of ocean currents. This assumption is in agreement with the actual state of things off the north coast during 1949. Now, in the summer of 1949, we had very bad yields especially up to 24. July when all

the fishing took place off the western part of the north coast. We find that the herring which was caught during this period, consisted largely of old fish, which could not have been expected to have come from Norway. Just at this time the long expected immigration year-classes came down to the coast further east. Practically all fishing thereafter took place off the most easterly part of the north coast. In connexion with this I should like to emphasize that not a single return was reported during the first period, but 40 in the second, and 75% of the tags were found in the most easterly factory, not a single tag in any factory on the western part of the north coast.

These are, I think, the most important things I have to say about herring taggings up to the present time. I am in no doubt that the experiment, when elaborated in the future, will provide a wide range of information. But we cannot expect really magnificent results before we have, let us say, 100,000 tagged herrings or more in the sea, and not until at least several years have passed.

10.

Tagging Experiments on Herring.

By

Hans Höglund

In the first half of March 1949 tagging experiments on herring were carried out on board the "Skagerak" at the northernmost part of the Bohuslän skerries on the west coast of Sweden.

Mr. Lea's hydrostatic marks were used and the method of application was that devised by him.

All together 525 fish were tagged and released. The first 153 specimens were caught in anchored gill-nets. These fish were somewhat out of condition; many of them being invisibly injured by the meshes of the net and some having too many scales scraped off.

The last batch of 372 fish were taken from pound-nets, and this method of capture turned out to be very satisfactory, as they were caught in shallow water, had all their scales intact and were in excellent condition.

The fish were confined in large live vats with circulating sea water on the deck of the "Skagerak". From the vats they were taken one at a time in tagging "cradles" into the ship's laboratory where the tagging operation took place. Scrupulous care was taken not to touch the fish by hand. After marking the herrings were gathered in another live vat and liberated in small shoals, 20 to 40 at a time, by dipping the whole vat into the sea and turning it over.

In the beginning we were content just to mark and release the herring without making any special notes, but later we found it possible to measure their lengths by means of a centimetre gauge at the bottom of the cradle and also to take scale samples.

Until the end of 1949 nineteen herring have been recaptured, two being of the gill-net caught specimens and seventeen of the pound-net caught.

The first recovery was made 10 days after the release and the latest had spent 289 days in the sea as a tagged herring.

During the first six weeks six specimens were recaptured within a distance of 10 nautical miles from the place of liberation. If there were any potential migrators among them they evidently had not yet begun to move. An additional, seventh, herring (spring spawner) was recaught in the vicinity of the place of liberation, but, in this case, not until 9.5 months after the release. Nothing, of course, is known as to its whereabouts in the meantime.

Twelve fish had migrated from 35 to 340 nautical miles. Among these, six were retaken in the open Skagerak, one off Jomfruland on the south-east coast of Norway, one to the north of Hanstholmen, one off Presteskiaer between Lister and Eggerö on the south-west of Norway and, finally, two on the Fladen Ground area and one between Fladen and Dogger Bank.

The gear of recapture have been herring gill-net, herring trawl, purse seine, mackerel drift-net and even hook.

In fifteen cases the recoveries have been made by the fishermen themselves; in four cases, however, the tags have not been observed until the catches were landed and distributed to factories or fishmongers in Denmark, Holland and Sweden.

In four cases the tags only, without the fish, have been returned owing to the loosening of the tag when the fish were recaptured.

By the aid of the scales and the stage of maturity it could be established that eight of the recaptured fish were spring spawners and five were autumn spawners. In the remaining six cases nothing about the spawning type could be said for certain.

Of the autumn spawners, two were recaught on the Fladen Ground, one between Fladen and Dogger Bank, one to the north of Hanstholmen and one to the north of Skagen.

The Fladen caught specimens are extremely interesting in so far as they form a very tangible support to the conclusion which Dr. K. A. Andersson has already drawn from other evidence, viz., that the autumn spawning herring trawled on the Fladen Ground in July—September and the so-called "winter-herring" occurring in the eastern Skagerak and off the Bohuslän coast from December to March, belong to the same type.

Map showing the places and dates of recaptured herrings tagged and released on the west coast of Sweden between the 4th and 14th of March 1949.

A second tagging experiment was made at the end of August on board the "Skagerak"; this time on the Fladen Ground and to the north of it. The weather was fine and did not hinder the work, but difficulties arose in getting a sufficient number of live and uninjured specimens from the trawl catches. Coming from a depth of 100—150 m., most fish but fortunately not all, had their swim bladder so inflated as to float belly up at the surface. Those specimens were all discarded for tagging purposes and only such individuals as were able to swim normally and had most of their scales intact were used.

As there were only 10 to 20 specimens fit for tagging in each haul, we did not succeed in marking more than 399 herrings on this North Sea expedition.

Until the end of February 1950 two recaptures only have been made, both in the North Sea and only a short time after the release.

APPENDIX

Racial Analyses of Icelandic Herrings by Means of the Otoliths.

By

Hermann Einarsson

Introduction.

A. Discussion of Problems.

The herring spawning in Icelandic waters consist of two seasonal races or spawning communities, the one spawning during spring (March) and the other during summer (July). Sæmundsson (1906) was the first scientist to point this out, and all subsequent investigations on adult herring (Johansen 1921, 1926, Runnström 1936, Friðriksson 1943, 1944, 1949) and fry (Jespersen 1920, Tåning 1936) have corroborated this important division of the Icelandic herring.

It is well known that seasonal races, i. e., spring, summer and autumn spawning communities, occur in the waters around the British Isles, in the North Sea, Skagerak and the Baltic, but the Norwegian herring, on the other hand, seems to be a relatively pure stock of spring spawners, only occasionally mixed with other elements (North Sea herring and Icelandic summer spawners (Rasmussen 1940)).

The definition and determination of the races of herring has been one of the most difficult tasks that have occupied herring experts since they started investigations. The methods of determination were greatly improved by Heincke (1898) who introduced maturity stages and arithmetic means of body characters, especially the number of vertebrae, as a means of discrimination.

In spite of intensive work, the problem of race determination has not been satisfactorily solved. Investigations on spawning herring have certainly given good results, the degree of maturity being a reliable criterion, but during certain periods of the year this criterion may fail and racial analyses become impossible. Neither is it possible, in areas where different seasonal races occur, to identify immature herring with any degree of certainty, at least not with our present methods. The difficulties increase where fishing is mainly carried out in other than the spawning seasons, when races cannot be accurately determined by means of the degree of maturity. Furthermore, the catches may consist, more or less, of immature herring, constituting a mixture of races, as far as can be judged from the use of arithmetic means of body characters. This applies to the southern Icelandic herring fishery in Faxa Bay and adjacent waters. During the main fishing season the usual methods of race determination cannot be used with these herring.

With regard to the herring in Scottish waters and in the North Sea Johansen (1924), Wood (1936, 1937) and others have successfully applied the method of race discrimination based on meristic characters, i. e., number of vertebrae and keeled scales. But Wood (1936 p. 33) points out that "Our greatest problem is the identification of the groups forming the obviously mixed herring population, which maintains the Scottish Summer and Autumn Herring Fishery". When discussing the adult herring population of the northern and north-western North Sea before the autumn spawning season, this author states (l. c., p. 38—39): "This large group might have been subdivided into classes according to their maturities and time of capture, and in some cases it will be necessary to do so, but such grouping is full of pitfalls, for although most scientists are familiar with and generally use the scale of maturities here adopted, one cannot assume that all the herring of a certain maturity at a given time have the same spawning season or belong to the same spawning population." This is the problem put in a nutshell.

Now, it is obvious what consequences we have to face, if race discrimination cannot be carried out. By far the most important of these is the fact that age analysis, which plays such a significant rôle in

all fishery research, cannot be correctly accomplished. This is caused by the circumstance that summer and autumn hatched herrings do not form a winter ring in the scales during their first winter of life, while the first winter ring in the scales of the spring spawners is formed during the first winter. Herrings of spring stock and summer or autumn stock, with the same number of winter rings in the scales, do not belong to the same year-class. The summer spawners are about 6—8 months older than the spring spawners, with the same number of winter rings in the scales, and are hatched in the year preceding that in which the spring spawners are born.

By the term "year-class" we ordinarily understand the broods hatched during the calendar year. This term can of course be given another definition. As a matter of fact, this has been done by HODGSON (1930). According to his definition the "year-class" includes fish born in the period August—January. However, this is no solution of the problem we are discussing; it is only one way of avoiding it. The seasonal broods must be treated together, and therefore we are not in a position to say anything about their relative strength or their characteristics from the point of view of age distribution, which is the goal we are aiming at.

There is obviously a possibility of distinguishing the seasonal races by a method which we have not considered as yet. It is a reasonable assumption that summer spawners have larger central areas in the scales than the spring spawners, viz., the summer spawners attain greater size before the first winter ring is formed than the spring spawners, because of their 6—8 months longer span of life. Observations that this opinion holds good were already made by DAHL (1907), and LEA (1910) records measurements which substantiate this.

However, later investigations have shown that a considerable degree of overlapping is experienced, making the actual use of this characteristic highly problematical in practice. On the other hand, useful information on the presence of different seasonal races was gained by this method by HODGSON (1929, 1930, 1936). MOLANDER (1918) and ANDERSSON (1946) have also used this characteristic to distinguish between seasonal races of autumn and spring spawners in the Skagerak. However, the present author gets the impression that it is rather the scale type than the actual size of the central area, which guides ANDERSSON in his determinations. This is also indicated when he states: "The scale illustrations (Figs. 2—5) are intended to show the difference between large and small central areas. It is difficult to define exactly the difference between them, but by comparing the size of the central areas with the breadth of the immediately contiguous summer zone, it is as a rule easy enough to determine whether the central area should be counted as large or small. But, as would be expected, there are cases in which it is impossible to say whether the central area should be called large or small." (l. c., p. 37).

B. On the Characteristics of the Seasonal Races of the Icelandic Herring.

a) Maturity Stages.

The definitions of the maturity stages, used in the present paper, are those given by HEINCKE (1898) and JOHANSEN (1924), with only very slight modifications. The definitions used were kindly placed at my disposal by Mr. O. AASEN. They are used as the basis for maturity determinations in the Norwegian herring work of recent years and a comparison which we were able to carry out at the Fisheries Directorate in Bergen shows a very good agreement between the determinations recorded in this paper and the Norwegian maturity determinations.

The definitions we have adhered to are the following:

Stage I	Immature herring with very small gonads just underneath the vertebral column. The female has wine-red torpedo-shaped ovaries, 2—3 mm. broad. No eggs can be seen with the naked eye. The male has whitish or grey-brown knife-blade-shaped testes, of 2—3 mm. breadth.
Stage II	Immature herring. The gonads are formed more like those of the grown-up individual, but are still small, about 5—6 mm. broad. The eggs are not visible to the naked eye.
Stage III	The gonads are thicker and more swollen, about 1—2 cm. broad. The eggs are small but visible to the naked eye. The ovaries yellowish, the testes white.
Stage IV	The gonads almost as long as the body cavity. The ovaries orange coloured with large, uneven, opaque roe. The testes white.
Stage V	The gonads fill up the whole body cavity. The ovaries of yellowish colour with round eggs, some of them hyaline. The testes white, the milt not flowing.
Stage VI	Flowing roe and milt.
Stage VII	Spent herring. The gonads slack. The ovaries with a few eggs left. Testes blood-red.
Stage VIII	Recovering spent herring with the gonads in firmer condition. The colour dark wine-red, about 1 cm. broad.

Unfortunately, the maturity determinations of the Icelandic herring material have not been uniform and in accordance with the definitions given above. In fact, the author's attention to the race problems of the Icelandic herring was originally aroused by observing the great diversity of maturity stages found during the summer fishing off the north coast of Iceland. This is not indicated by FRIÐRIKSSON's (1944) results, as he records about 80—95% as being in maturity stage III, which is considered typical for a spring spawning race at this time of the year (June—Sept.). It can be said with certainty that this result

is due to a judgment of maturity stages that differs from the definition given above, viz. ovaries in which the eggs are not visible to the naked eye have been recorded as stage III, when they should be classified as stage VIII. When the north coast herring were examined according to the definition used in this paper, during the summer of 1948, the result was the following:

Mat. Stage...	II	III	IV	V	VII	VIII	Total
%	1·5	59·9	2·8	0·1	2·5	33.2	100

Accordingly, we cannot use the maturity determinations made on the north coast herring prior to 1948 for comparison with the results recorded here.

However, we have not found it difficult to distinguish stage III and VIII, although doubtful and transitional cases are frequently encountered. Our main obstacle was to distinguish stage VIII and stage II—III. These stages look very similar. The ovaries and testes may have approximately the same size, and in both cases the eggs are not visible to the naked eye. A controlling test shows that inaccuracies in our results may occur because of these difficulties.

An examination of 198 herrings (sample 37/49) was carried out on Dec. 16th 1949, while 100 herrings of the same catch were kept in frozen condition until Febr. 20th 1950 and then examined. A comparison of the results shows the following:

Mat. Stage...	II	III	IV	V	VIII	Total
16. Dec.	14·2	20·7	38·9	2·0	24·2	100 %
20. Febr.....	9·0	19·0	36·0	1·0	35·0	100 %

It will be seen that there is a better agreement between stages III, IV and V than stages II and VIII and we are not quite sure that our judgment has been exactly comparable on the two occasions with regard to these last two stages of maturity. But we do not think that this affects the results seriously, and this is in fact confirmed by the analysis mentioned. According to these considerations, we must emphasise that stage VIII may include a certain number of individuals that have not spawned before and are in reality in maturity stage II—III. All through our investigations we have been aware of this uncertainty and we have not as yet found any way of correcting it.

We have endeavoured to avoid interpretations as to the sequence of stages, as this might affect our judgment at different times. With this in mind, we did not examine the samples taken during July, August and September in the same order as they were received. Instead, they were examined at random. Secondly, we did not make any survey of the results until the collection of data was finished. All the maturity determinations were made by the same person, my assistant Miss Hulda Jónasdóttir.

The earlier investigations of Johansen (1921, 1926) and Runnström (1936) were based on collections taken during the spawning period of the two races respectively, and the races could thus be correctly identified by means of the degree of maturity. On the other hand, more recent investigations by Friðriksson (1949), on herrings caught in the inner part of Faxa Bay and Hvalfjörður during the years 1947—1948, were based on collections that included immature herrings to a considerable extent. This was especially true about February 1947, when the 3-ringers were the dominating component. Friðriksson does not distinguish between the broods when estimating the strength of the year-classes. He maintains e. g. with regard to the collection from February 1947, that "The dominating year-class is the 3-year-old herring representing the brood from 1944 . . ." (l. c., p. 39). In our opinion this is erroneous, as the material consists of a mixture of the two seasonal races. The 3-ringers represent the broods from the summer of 1943 and the spring of 1944.

On the other hand, most of the collections taken in the latter half of 1947 and the beginning of 1948, could be analysed according to race by means of maturity stages. During this period the spring spawners were mostly in maturity stages IV and V, while the summer spawners were predominantly in maturity stage VIII (designated as III by Friðriksson).

b) Vertebral Numbers.

Figure 1 gives a survey of the data relating to vertebral numbers of the two seasonal races respec-

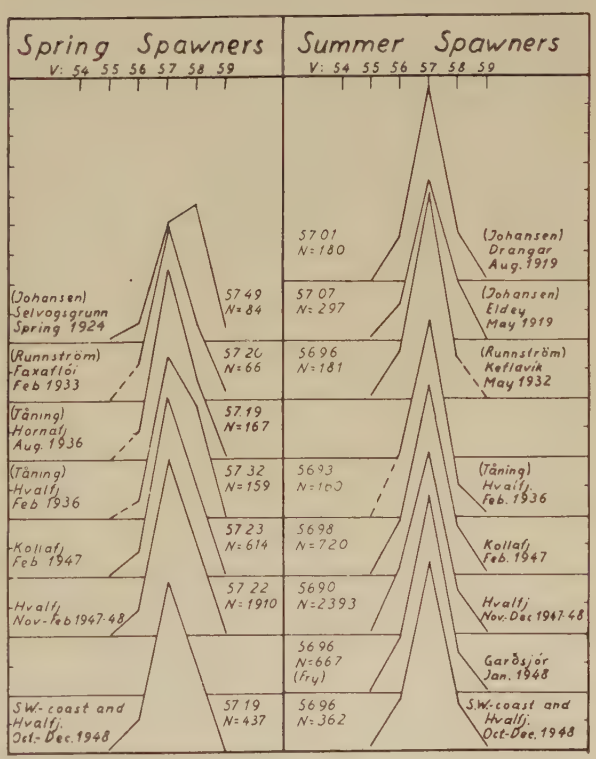


Fig. 1. Vertebral number of Icelandic spring spawners and summer spawners shown by variation polygones.

tively. The vertebral numbers of the adult herring from the period 1947—1948 have been compiled from the same data which are given in a more condensed form by Friðriksson (1949). The length of the fry of summer spawners caught in Faxa Bay in January 1948, was between 2·5 cm. and 4·5 cm. Before counting the vertebrae, the specimens were stained by the alizarin method.

It will be seen that the earlier records given by Johansen were somewhat higher than those found later. This is probably due to different hydrographical conditions on the spawning grounds in the years around 1920. On the other hand, it will be seen that the mean vertebral numbers are surprisingly stable in recent years. The mean numbers of Vert. S of the spring spawners are about 57·19—57·23 while the mean numbers of the summer spawners are about 56·93—56·98. The means are thus of considerable importance for testing the correctness of racial analyses and intermediate means indicate invariably (provided the samples are large enough) that we are dealing with a mixture containing both races.

c) Size of the Central Area of the Scales.

The possibility of distinguishing the two seasonal races by means of the size of the central areas was considered first of all. Scale measurements were available, and maturity stages and vertebral numbers showed that the collection consisted of both races. The length at the formation of the first winter ring (l_1) was calculated, with the results shown in the graphs Figure 2.

The 3-ringers caught in February 1947 cannot be divided into races according to maturity. The mean vertebral numbers suggest that spring spawners are the dominating component, as stages I and II have the mean 57·094 $\pm$ 0·046 vertebrae (n = 203) and stage III, 57·193 $\pm$ 0·042 vertebrae (n = 244). Neither is it possible to divide the collection into races according to the size of the central area. On the other hand, the graphs show quite clearly that specimens having large initial growth mature earlier than those having smaller central areas, a fact which was established by Lea (1913, Tables 26, 27, p. 30).

The measurements of the 4-ringers taken during November—February 1947—48, do not result in a two-peaked curve, as will be seen from Figure 2. Neither do the curves, resulting from the separation into maturity stages, give any support to the opinion, that size before the formation of the first winter ring can with advantage be used as a distinguishing characteristic of the two races. The mean numbers of Vert. S show that maturity stages divide the collection according to race. Maturity stages IV and V have the means 57·219 $\pm$ 0·038 (n = 302) and 57·187 $\pm$ 0·026 (n = 560) respectively, and thus comprise spring spawners. Maturity stage III has the mean 56·946 $\pm$ 0·025 (n = 649), which is characteristic for summer spawners. The stage designation used by Friðriksson (1949) is adhered to here, and it must be remembered that the III-stage of this author includes the VIII-stage according to the usual definition of these stages.

From the above, it is considered that the character just discussed cannot be used for distinguishing the seasonal races of the Icelandic herring.

d) The Herring Otolith as a Guide to Race.

Next, attention was directed towards the herring otoliths from the following considerations:

1. The formation of the scales of the herring does not begin until the young herring is about 4—5 cm. in length, and that is approximately the size increment of the summer spawners during the autumn and winter months. Therefore, this phase in the life history of the herring will not be reflected in the structure of the scale. The otoliths, on the other hand, are present from the larval stage onwards.

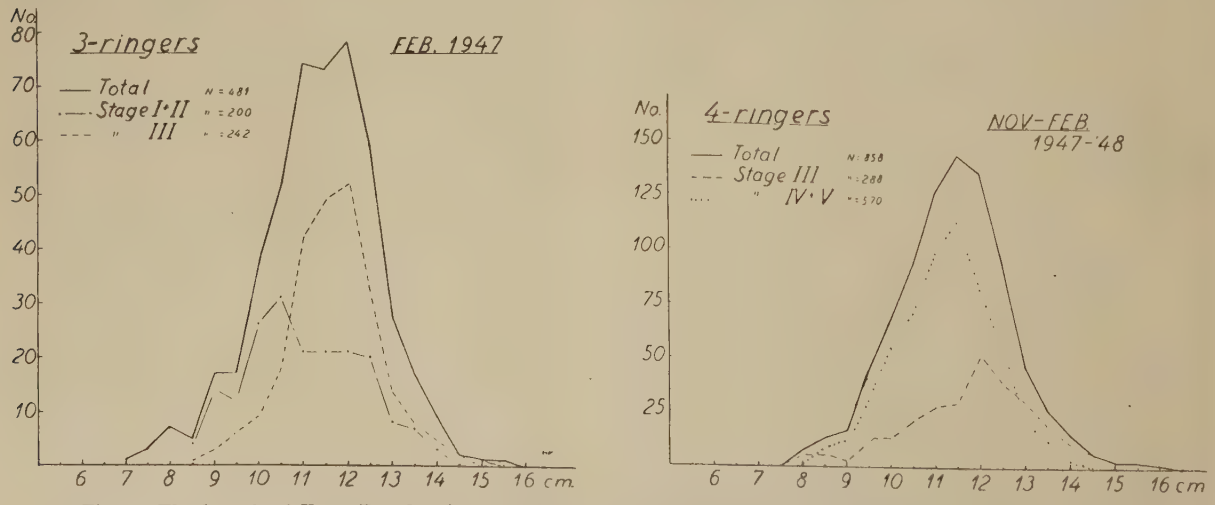
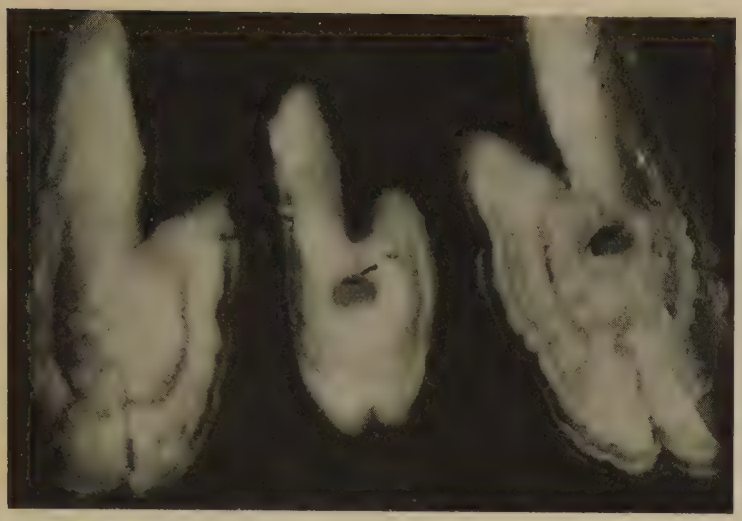


Fig. 2. The length of Faxa Bay herring at the formation of the first winter ring in the scales, calculated from scale measurements.



a b c

Fig. 3. Typical otoliths of spring spawners and summer spawners showing the difference in the appearance of the nucleus.
a) otolith of a Norwegian spring spawner, with 3 winter rings.
b) otolith of an Icelandic summer spawner, with 2 winter rings.
c) otolith of an Icelandic summer spawner, with 11 winter rings.

2. The larval and post-larval stages of summer and spring spawners develop during different seasons of the year, i. e., under different growth conditions that may be reflected in the structure of the otolith nucleus.

Otoliths from herrings caught in Hvalfjörður in February 1948 were examined, and differences in the appearance of the otolith nuclei were at once noticed. A preliminary description of these differences was published (Einarsson 1949).

Typical examples of these differences are shown in Figure 3 a—c. It was found that some otoliths have hyaline nuclei while others have opaque nuclei. This difference was explained as being due to different seasonal growth conditions during larval and post-larval life. It was found that otoliths from Norwegian spring spawners mostly have opaque nuclei, as shown in Figure 3 a. The opaque nucleus was considered as corresponding to the opaque summer zone formed during a period of rapid growth. On the other hand, the hyaline nuclei were considered as corresponding to the winter rings formed during a period of slow growth, viz., in the larval and post-larval life of the summer spawning herring.

It was observed that intermediate structures occurred, which made an immediate use of these characters impossible. An analysis of their frequency and a detailed examination of the range of variation was imperative. This is the main theme of the present paper, together with a presentation of data, showing the practical application of this method of distinguishing the seasonal races of the Icelandic herring.

C. Previous Observations relating to Herring Otoliths.

Only four references have been found relating to the characteristics of herring otoliths. Curiously enough, the earliest contains at the same time the first successful age analysis of herring. This little known, but very interesting, paper is that of Jenkins (1902). As is more widely known the first age analyses by means of the scales were carried out by Broch (1908) and Dahl (1907).

It is indeed interesting to note that Jenkins' investigation was carried out for exactly the same purpose and from similar considerations that led to the present investigations. After having referred to Reibisch's explanation of the formation of different zones in the otoliths of the plaice, Jenkins came to the conclusion that the spring spawners should have light cores in the otoliths, and the summer spawners dark cores, when viewed in transmitted light. His observations did not support this, for, according to his opinion, both forms had light cores. In fact, the opposite is true about the Icelandic races, the spring spawners having dark and the summer spawners light nuclei when viewed in transmitted light. On the other hand, the present author has found it very difficult to observe the characteristics of the otoliths in transmitted light. Jenkins' figures (Tafel III, Fig. 1—9) show very indistinctly the appearance of the nucleus, but as far as can be judged they most resemble those of atypical spring spawners which seem to be frequent in local fjord populations (Oslofjord specimens being investigated by the present writer). These often have a transparent nucleus, but with a blurred appearance, and do not show the marked transparent area, characteristic of the Icelandic summer spawners.

Another difficulty may have had considerable influence on Jenkins' results. The spawning periods of the different races may be fairly close in certain areas, as for example, the Baltic, and thus intermediate types would be formed which would make identification impossible. Jenkins states that he found mature or nearly mature herrings in almost every month of the year (l. c., p. 121).

No observations relating to these characteristics

are known to the present author other than the paper of Birtwistle and Lewis (1922) which mentions, that herring otoliths from the Irish Sea have a transparent nucleus. They state: "The transparency of this nucleus strengthens the assumption that herrings having otoliths with transparent nuclei are autumn and winter spawned." (l. c., p. 65). However, the authors made no comparison between these otoliths and the otoliths of spring spawners from the same area.

The most important work on herring otoliths was made by Lissner (1925), who gives a detailed description of their structure. But he discourages every effort to use their characteristics for the purpose of race discrimination. After having referred to Birtwistle and Lewis's observation, Lissner writes: "Man müsste daraus schliessen, dass, analog den Verhältnissen bei der Scholle, Frühjahrsheringe einen opaken Kern haben. Dies ist jedoch, wie aus den hier gegebenen Beschreibungen hervorgeht, nicht der Fall. Bei den Norwegischen Heringen ist allerdings der hyaline Kern oft nur schwer nachzuweisen, ist aber auch vorhanden. So unterscheiden die beiden Heringsformen sich z. T. nur durch die verschiedene Ausdehnung des hyalinen Kerns." (l. c., p. 187).

The observations recorded in the present paper do not substantiate Lissner's statement that Norwegian herring otoliths always have a hyaline nucleus. The overwhelming majority of these otoliths have opaque nuclei, without any visible trace of a hyaline centre. On the other hand, it is quite true that spring spawners may have hyaline nuclei, and we have to examine whether these resemble the nuclei of summer spawners sufficiently to make identification impossible.

Other characteristics of the otoliths have more recently been used for race discrimination by Erdmann (1937, 1938), who found that the outer contours of the otoliths together with a characteristic appearance of the annual growth zones made race identification possible. Erdmann states (1937, p. 48): "Unter den Statolithen traten nun solche auf, die sich durch einen eigenartigen Aufbau hervorhoben. In groben Zügen angedeutet, bestand diese Eigenart in einem typischen Umriss des Statolithen und in einer scharfen Abgrenzung der jährlichen Wachstumsringe, welche die Träger dieser Statolithen als zu einer besonderen Gemeinschaft gehörend kennzeichnete. Diese Heringe wurden "blind" aus dem Protokoll herausgezogen, d. h. ohne Rücksicht auf die übrigen Eigenschaften der Individuen. Die angedeuteten Merkmale der Statolithen sind so ausgeprägt, dass es fast in allen Fällen möglich ist, schon an einem Splitter den Typ zu erkennen."

The present author examined a small sample of otoliths from Scottish autumn spawners, and these were found to differ in appearance from those of the Icelandic herring. Firstly, they are considerably thicker and the hyaline central area is only occasionally as well defined as in the otoliths of Icelandic summer spawners. Secondly, the sulci along the edges are more numerous. Especially the thickness, and the numerous sulci give these otoliths a very characteristic general appearance. These observations seem to support Erdmann's statement that the contours may well be of significance in race discrimination. It is to be hoped that a closer study will be made regarding the significance of these characteristics.

D. Age Determination by means of Herring Otoliths.

The examination of otoliths of the southern Icelandic herring showed that these were excellent for the purpose of age determination, especially when dealing with herring of less than 10 years of age.

The herrings in Faxa Bay and adjacent waters are mostly caught in drift-nets and frequently the scales are damaged or lacking. On the other hand, the otoliths are securely preserved inside the head, can be quickly removed, and are more easily mounted for inspection than the scales. When we are not sampling material for growth or scale type studies, we therefore follow the practice of taking otoliths from every herring examined, but scales are always taken from herrings exceeding 33 cm. in length. By adopting this procedure we have a double check on all herrings that may give difficulties in age determination.

Structural Characteristics of Otoliths of Spring and Summer Spawners.

A. Material and Methods.

The fact that the Norwegian herring is a relatively pure spring spawning stock affords an excellent opportunity to study the characteristics of this race. Four samples of herring otoliths were procured and the variation of the appearance of the otolith nuclei was examined.

The variation in these characteristics, as seen in the otoliths of the Icelandic summer spawning herring, was examined in a sample of young herring from North Iceland.

For testing the results arrived at, large collections of otoliths of the herring in Faxa Bay and adjacent waters were sampled during 1949. The investigations on Icelandic herrings are based on an examination of 6995 herrings.

The otoliths were inspected under a binocular microscope, by direct light, and they were mounted in the following way: A round hole of about 1 cm. diameter was cut into a piece of cardboard. Black paper was then stuck on the one side of the cardboard, for a black background is the most suitable when inspecting the otoliths. In this hole the otoliths are imbedded in a drop of Canada Balsam, in which the hyaline zones become very clear and marked. For closer study only one pair of otoliths was mounted in

Fig. 4. A sample of otoliths showing the method of mounting.

a cardboard of the size of a usual glass slide, but for routine analysis 50 pairs were mounted in a bigger cardboard, carrying 50 holes. (Fig. 4.)

B. Otoliths of Norwegian Spring Spawners.

The variation in the appearance of the otoliths of Norwegian spring spawners can be classified as follows:—

Type VA. The otolith has an opaque nucleus without any visible trace of a hyaline area when viewed in direct light (Fig. 3 a).

Type VB. Small hyaline centres are visible (Fig. 5a).

Type VC. The hyaline nucleus is conspicuous (Fig. 5 b). The hyaline centre is concentric, the margins blurred, and small fissures with opaque material traversing it.

Type S. The hyaline nucleus is very conspicuous and resembles closely the nucleus of summer spawners.

Only the first type is more strictly defined. The reference to the remaining types must be according to a subjective estimate, and is only intended to show the approximate frequency of the variants.

The maturity stages noted and the mean vertebral number of the samples are shown in the following table.

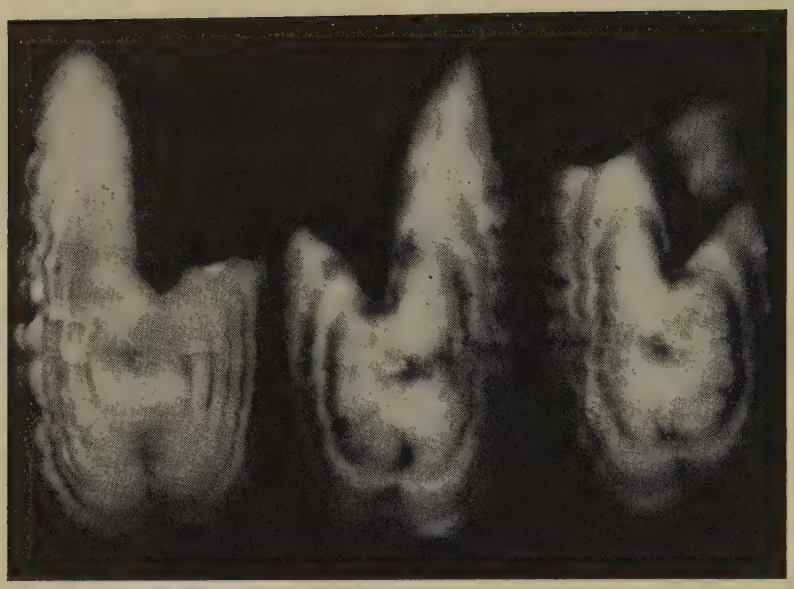
Sample No. / Mat. Stage	II	III	IV	V	VI	VII	VIII	Total	Av. No. of V
N 1.....	—	1	52	46	—	—	1	100	57·220
N 2.....	1	1	54	43	—	—	1	100	56·830
N 3.....	—	—	21	47	32	—	—	100	57·110
N 4.....	—	—	13	34	52	1	—	100	57·121

The four samples examined give the following result when divided according to type of otolith.

Sample No. / Type	VA	VB	VC	S	Total
N 1.....	83	10	—	1	94
N 2.....	85	12	1	1	99
N 3.....	86	12	1	1	100
N 4.....	80	11	6	—	97
Total number	334	45	8	3	390
%	85·6	11·5	2·1	0·8	100

This table shows that the variation in the appearance of the first growth zone of the Norwegian otoliths is very slight indeed, as 85·6% conform to the type assigned to the spring spawning brood. The VB type constituting 11·5% may resemble the SC type described later, and the VC type may be confused with the SB type. It is not possible to give definite rules to follow in these difficult cases, beside those given in the definition. Each worker must first acquire practice, by routine examination, in distinguishing these stages before an analysis can be carried out, just as is the case when spawning zones of cod otoliths or scale types of herring are being dealt with.

It is noteworthy that the two VIII-stage specimens, belong, according to the otolith analysis, to a summer spawning race. The otoliths resemble closely those of the Icelandic summer spawners and it is in fact probable that the specimens belong to that race. One spring spawner also had an otolith that resembled



a b

Fig. 5. Otoliths of Norwegian spring spawners, a) showing an example of type VB and b) of type VC.

the otoliths of summer spawners so much that it could not be distinguished from the latters.

C. Otoliths of Icelandic Summer Spawners.

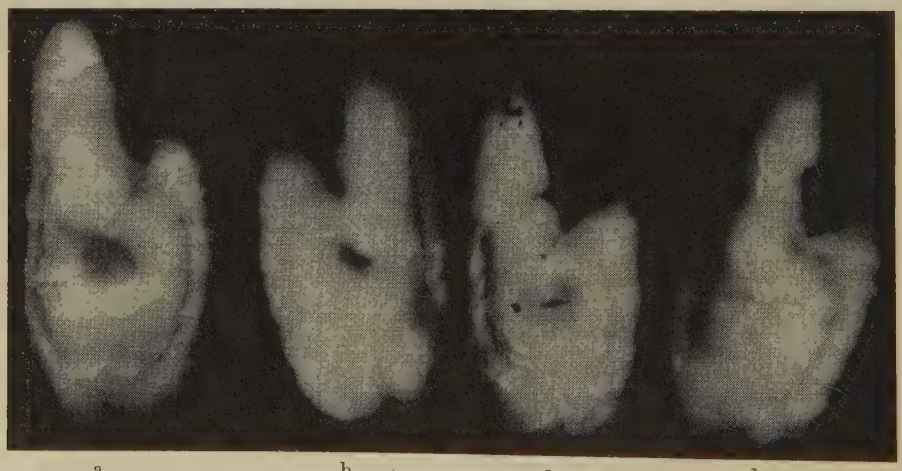
A sample of otoliths from young herrings was taken in the harbour of Akureyri in March 1949. These herrings were all immature (maturity stage I), and the mean vertebral number was found to be 56·864 (n = 300), which may be considered typical of the Icelandic summer spawning race. 290 of these herrings had two winter rings on their scales, and these have been examined with regard to the variation in the structure of the nucleus.

This collection has been divided into four categories, which are defined in the following way:

Type SA. A large well-defined hyaline nucleus is present (Fig. 6 a).

Type SB. The hyaline centre is smaller but well defined, and the opaque zone sometimes narrows it to an oval or irregular depression (Fig. 6 b).

Type SC. The hyaline nucleus is only a narrow transverse groove, making the appearance as if the opaque part had partly covered the hyaline area from two different sides (Fig. 6 c).



a b c d

Fig. 6. Otoliths of Icelandic summer spawners, a) showing an example of type SA, b) of SB, c) of SC and d) of SD.

Type SD. The hyaline nucleus is not visible, but a transverse groove can be discerned, indicating that a coalescence has taken place (Fig. 6 c).

Only the first type can be more strictly defined, as was the case with the V types. The numbers of the other groups are only approximate, in order to give an idea of the frequency of the variants.

The analysis of the sample resulted in the following figures:

Type.....	SA	SB	SC	SD	Total
Number.....	196	49	33	12	290
%.....	67·6	16·9	11·4	4·1	100

Assuming that we are dealing with a pure stock (since size and vertebral number do not indicate mixture), we are faced with considerable difficulties here. It is easy to distinguish type SA from the V types, and type SB is also fairly easy, although it may sometimes resemble type VC, but the nucleus is clearly defined and has not the blurred character of type VC. On the other hand the remaining types SC and SD present many difficulties, although the transverse form of the central groove is in most cases characteristic.

D. Discussion.

The main obstacle with regard to the use of the otolith as a guide to race lies in the fact that sometimes the hyaline nuclei in the otoliths of summer spawners are covered by opaque material. It has been repeatedly observed that while one otolith belongs to the SA type, the other from the same herring, has no visible hyaline area or only a very indistinct one. One of these otolith pairs is shown in Fig. 7.

However, experience shows that these difficulties can, to a considerable degree, be overcome with routine practice and that the method can be successfully applied to material when no other criteria of seasonal races are available. The possibility of error in the determinations of the otoliths should, however, always been borne in mind. Some error must be expected, and the limitations of the method have not been fully examined as yet. But the results recorded below show, in the authors opinion, that these errors cannot be of any noteworthy significance. The parallelism experienced between the degree of maturity and otolith type during the first period of investigation and then again during the fourth, was decisive enough for the author's confidence in the method.

The following analysis was carried out on material collected during the period May to December 1949. When damaged and doubtful cases were excluded this collection comprised 6695 herrings.

The primary object was to become intimately aquainted with the variation in the appearance of the otolith nuclei in the two races. To this end 6 samples, taken in the period 20. May to 23. June, were examined. The vertebral numbers of the different maturity stages indicate that maturity alone could be used as a distinguishing characteristic at this time of the year. Accordingly, the otolith collection could be divided into two portions, one including spring spawners and the other summer spawners.

The examination of these portions showed that on closer inspection the S-types could always be identified in herrings of maturity stages IV and V, while these types were only occasionally observed in herrings of maturity stage VIII, which was typical of the spring spawning stock at this time.

Fig. 7. Two otoliths from an Icelandic summer spawner, showing different appearance of the nucleus.

The writer therefore worked according to two main assumptions: 1. that during this period the degree of maturity was the true index of race, and that the few S-types observed in maturity stage VIII really belong to maturity stage II—III, which we have had difficulty in distinguishing, as already shown, and 2. that a herring hatched in spring also spawns in spring, and a herring of summer progeny also spawns during summer. In other words, there are no "crossings over" from race to race.

The two series were closely and repeatedly examined in order to study the characteristics of the two respective races, and gradually a greater degree of accuracy in assigning the otoliths to the series and the types defined above was achieved. The author then felt confident that an otolith analysis could be made of material collected in a season when the degree of maturity is an unreliable criterion.

Verification of the Otolith Method of Distinguishing Seasonal Races.

The period of investigation can be divided into three parts, according to the suitability of maturity stages for the purpose of race discrimination:

1. From 20. May to 23. June, when there is a close agreement between maturity stage and race.
2. From 21. July to the beginning of October, when maturity stages are only of very slight value as a distinguishing feature.
3. From the beginning of October to the end of the year when there is again a close agreement between maturity stages and race (sample 33/49, taken 16. Nov. being an exception).

During the summer spawning, in the period 23. June to 21. July, no herring catches were made.

These periods will now be discussed separately.

A. 1st Period, from 20. May to 23. June.

a) Maturity Stages.

The maturity stages noted during this period are shown in the following table, where the maturity stages are tested as to vertebral number.

No. of V / Mat. Stage	II	III	IV	V	VI	VII(VIII)	VIII	Total
59.....	—	—	1	1	—	1	2	5
58.....	9	13	175	21	1	45	45	309
57.....	19	50	791	110	3	83	99	1155
56.....	1	15	193	30	2	16	9	266
55.....	—	—	5	—	—	—	1	6
54.....	—	—	1	—	—	—	—	1
No.	29	78	1166	162	6	145	156	1742

Mat. Stage	II	III	IV	V
M	57·276	56·974	56·975	56·957
m	± 0·096	± 0·068	± 0·017	± 0·045

Mat. Stage	VII(VIII)	VIII	Total
M	57·214	57·244	57·022
m	± 0·052	± 0·049	± 0·014

During this period the summer spawners are rapidly developing their genital organs prior to spawning. This seasonal race is in maturity stages III, IV, V and VI. The arithmetic means of vertebral numbers are in accordance with this fact as is seen by comparing them with those previously recorded (see Fig. 1).

On the other hand, the spring spawners, which are but sparsely represented in all the samples, with the exception of the first one, are almost exclusively in maturity stage VIII or (in the first sample) VII(VIII). Most of the II-stage specimens belong also to the spring spawning race. The genital organs of the spring spawners are at this time of the year recovering or at rest.

b) Analysis of Otoliths.

As previously mentioned, 6 samples (Nos. 1, 2, 4, 5, 6 and 7) each containing about 200 specimens, were repeatedly examined until the author felt confident that discrimination between the races could be accomplished by means of the otoliths. Samples Nos. 8 and 9 were then analysed and the otolith types tested as to vertebral numbers with the following results:

No. of V	Otolith Type: SA	SB	SC	SD	Total	VA	VB	VC	Total
58...	35	18	8	10	71	7	5	1	13
57...	175	56	45	43	319	12	2	2	16
56...	48	14	11	16	89	1	1	—	2
55...	—	1	—	—	1				
54...	1	—	—	—	1				
No...	259	89	64	69	481	20	8	3	31

	SA	SB	SC	SD	Total S
M	56·955	57·022	56·953	56·913	56·952
m	± 0·037	± 0·076	± 0·065	± 0·043	± 0·027

This analysis confirmed our belief that the most difficult otolith types, i. e., SC and SD could be successfully distinguished from the V types. As will be seen from the table the types (with the exception of type SB) show vertebral numbers typical for the summer spawning race.

The final result of our analysis of the herrings caught during this period, is as follows, when tested as to mean vertebral number:

No. of V.	Summer Spawners	Spring Spawners	Total
59.....	2	2	4
58.....	213	103	316
57.....	969	190	1159
56.....	241	26	267
55.....	5	1	6
54.....	2	—	2
Number.....	1432	322	1754
M	56·972	57·245	57·022
m	± 0·016	± 0·034	± 0·019

c) Age Distribution.

We have now divided our whole material according to race, and we are therefore able to present a correct picture of the age distribution, which is shown in Fig. 8, where the respective percentages of the two races are also shown.

The age distribution of the summer spawners is strikingly similar in all the samples investigated, the 4-ringers (i. e. year-class 1944) dominating and constituting about 40—80% of the specimens examined.

The spring spawners, on the other hand, vary somewhat. In the first sample, taken off Eldey 20. May, the 4-ringers (i. e. year-class 1945) also dominate, while in the samples taken in Jökuldjûp between 23. May and 11. June, the 5-ringers (i. e. year-class 1944) are in the majority forming about 40—70% of the catches. The 10-ringers are also relatively important in these samples.

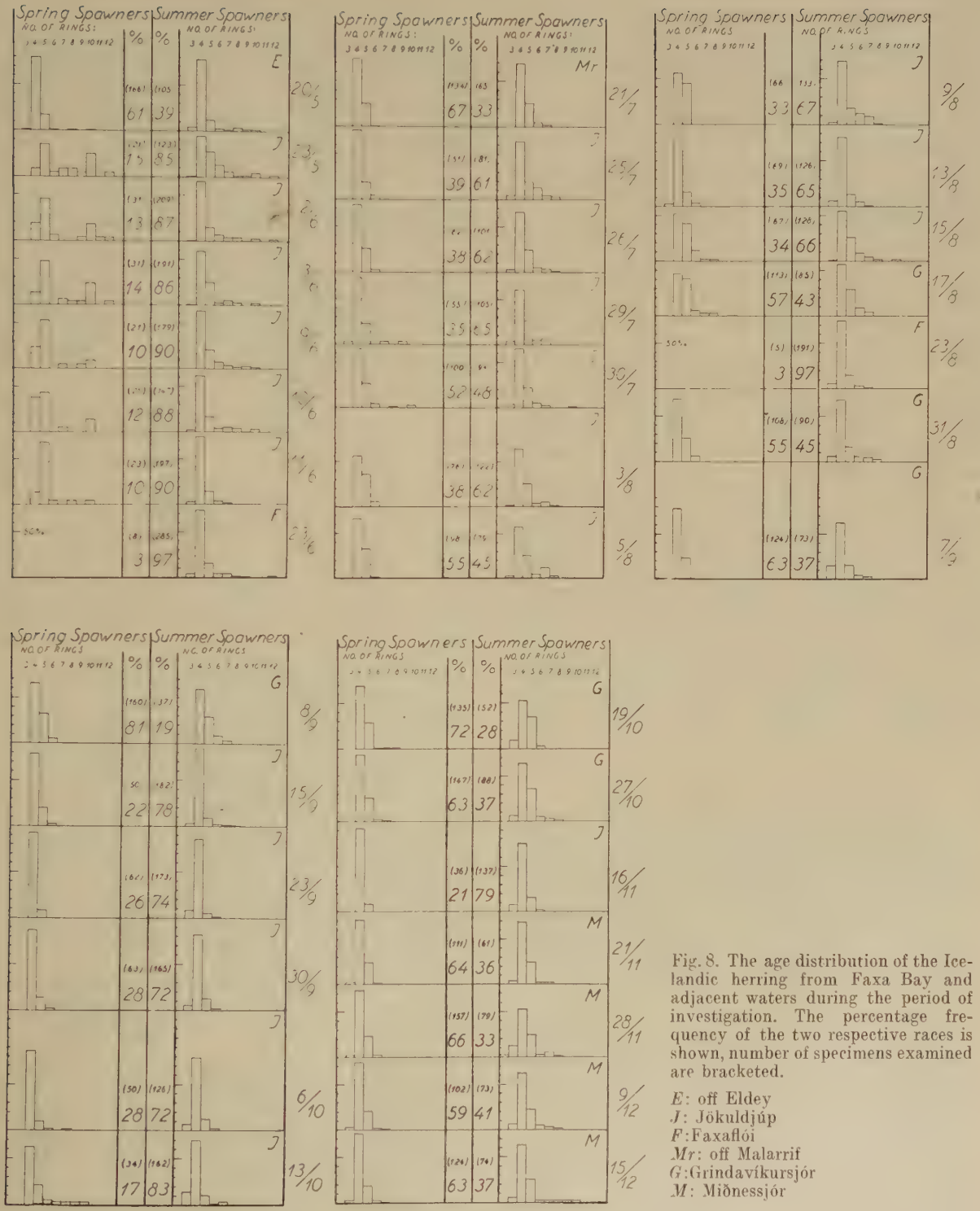


Fig. 8. The age distribution of the Icelandic herring from Faxa Bay and adjacent waters during the period of investigation. The percentage frequency of the two respective races is shown, number of specimens examined are bracketed.

E: off Eldey
J: Jökuldjúp
F:Faxaflói
Mr: off Malarrif
G:Grindavíkursjór
M: Miðnessjór

B. 2nd Period, from 23. June to 21. July.

During this period the summer spawning goes on and no herrings are caught in the drift-nets.

C. 3rd Period, from 21. July to 6. October.

a) Maturity Stages.

When the maturity stages observed during this period are tested as to vertebral number we get the following result:

No. of V / Mat. Stage	II	III	IV	V	VI	VII	VIII	Total
59	2	4	—	1	—	—	9	16
58	174	109	1	—	1	39	436	760
57	692	199	6	5	2	168	1315	2387
56	137	26	3	—	—	44	279	489
55	2	1	—	—	—	3	4	10
54	—	—	—	—	—	1	—	1
No.	1007	339	10	6	3	255	2043	3663
M	57·037	57·262				56·945	57·081	57·074
m	±0·018	±0·034				±0·040	±0·013	±0·007

From the vertebral numbers recorded in this table, we can conclude that only a very small part of the collection can be safely referred to seasonal race by means of the degree of maturity. It will be seen that the III-stage herrings are spring spawners (V = 57·262) and the VII-stage specimens summer spawners (V = 56·945), but the majority of the herrings, totalling 3050 specimens, or 83·3% of the collection, are in maturity stages II and VIII, which evidently constitute a mixture of both races, as clearly shown by the intermediate values of the mean vertebral numbers.

b) Analysis of Otoliths.

It is a very reassuring fact, established through the analysis of these difficult samples, that the writer's determination of the otolith types tallied completely with one degree of maturity, as the VII-stage specimens could always be identified as summer spawners by means of the otoliths. Further the overwhelming majority of the III-stage specimens could be determined as spring spawners by this method. The analysis resulted in the following two series: (see top of next column)

Spring Spawners.

No. of V / Mat. Stage	II	III	IV	VIII	Total
59	2	4	—	7	13
58	78	106	—	282	466
57	143	194	1	565	903
56	15	24	—	73	112
55	—	1	—	2	3
No.	238	329	1	929	1497
M	57·274	57·267		57·236	57·249
m	±0·038	±0·034		±0·020	±0·016

Summer Spawners.

No. of V / Mat. Stage	II	III	IV	V	VI	VII	VIII	Total
59	—	—	—	1	—	—	2	3
58	96	3	1	—	1	39	154	294
57	549	5	5	5	2	168	750	1484
56	122	2	3	—	—	44	206	377
55	2	—	—	—	—	3	2	7
54	—	—	—	—	—	1	—	1
No.	769	10	9	6	3	255	1114	2166
M	56·961					56·945	56·953	56·957
m	±0·019					±0·040	±0·017	±0·012

No. of V	Otolith Type							
	SA	SB	SC	SD	Total S	VA	VB VC	Total V
59	1	2	—	—	3	8	5	13
58	129	74	22	56	281	245	207	452
57	627	370	137	241	1375	500	373	873
56	176	84	33	62	355	56	49	105
55	4	1	1	1	7	3	—	3
54	—	1	—	—	1	—	—	—
No.	937	532	193	360	2022	812	634	1446

	SA	SB	SC	SD	Total S
M	56·945	56·980	56·933	56·978	56·958
m	± 0·019	± 0·025	± 0·039	± 0.034	± 0·013

	VA	VB VC	Total V
M	57·245	57·265	57·254
m	± 0·021	± 0·024	± 0·016

These two series, characterized by mean vertebral numbers which are quite typical for the two races respectively, show that by means of the otoliths we have succeeded in distinguishing the races independently of other criteria.

A further proof of the correctness of the race analysis by means of the otoliths, can be obtained by testing the various otolith types as to vertebral numbers. If appreciable errors had been made in dealing with the more difficult types containing mixture of both races, these should be reflected in the vertebral numbers. This test is shown in the above table, comprising sample 10/49—28/49 (sample 33/49 is not included in this analysis).

An examination of the mean vertebral numbers recorded in this table shows that there is not the slightest indication of mixing. The more atypical otolith groups have just as characteristic mean number as the typical ones.

The final result of the racial analysis for the period 21. July to 6. October (samples 10/49—28/49) is as follows, when tested as to vertebral number:

No. of V	Summer Spawners	Spring Spawners	Total
59	3	13	16
58	282	452	734
57	1380	889	2269
56	357	106	463
55	7	3	10
54	1	—	1
No.	2030	1463	3493
M	56·958	57·250	57·080
m	± 0·013	± 0·016	± 0·010

c) Age Distribution.

During this period and the following one the age distribution is very uniform as seen from the graphs in Fig. 8. The catches consist mostly of 4-ringers, i. e. year-class 1945 for the spring spawners and 1944 for the summer spawners. Second in order are the 5-ringers, i. e. year-classes 1944 and 1943. Other year-classes are insignificant throughout the period.

D. 4th Period, from 6. October to 15. December.

a) Maturity Stages.

Sample 33/49, taken on 16. November was treated together with the samples from the previous period, as maturity stages II and VIII in this sample, comprise a mixture of the two races. With the removal of this exception a good agreement between otolith types and maturity stages was observed throughout the period. When tested as to vertebral number the maturity stages show the following figures:

No. of V / Mat. Stage	II	III	IV	V	VII	VIII	Total
59..	1	1	6	—	—	1	9
58..	77	86	132	—	—	24	319
57..	377	229	262	1	1	129	999
56..	92	47	31	—	—	48	218
55..	3	—	1	—	—	2	6
No..	550	363	432	1	1	204	1551
M..	56·966	57·113	57·257			56·873	57·069
m..	± 0·025	± 0.032	± 0.029			± 0.044	± 0.016

It will be seen that the collection can be divided according to maturity stages and vertebral numbers into two units, the situation now being reversed when compared with the first period discussed. Now, the spring spawners are developing their sexual organs, being in maturity stages III and IV, while the summer spawners are in maturity stages II or VIII, i. e., their genital organs are recovering or at rest.

The vertebral numbers are in good accordance with the usual means found for the two races respectively, the III-stage specimens, however, showing a lower mean than usual. The otolith analysis did not reveal any admixture of summer spawners in this group, as will be seen from the following analysis. The average vertebral number of the whole collection shows an intermediate value, as usual.

b) Analysis of Otoliths.

With the exception mentioned above, there was a close conformity between otolith types and maturity during this period. The analysis of the otoliths gave the following result: (see top of next column)

The otolith types have also been tested as to vertebral number, for comparison with the results recorded for the previous periods. This test is shown in the following table (sample 33/49 is included in this analysis): (see next column)

The mean vertebral numbers of the various otolith types are all quite characteristic for the two races

Spring Spawners.

No. of V / Mat. Stage	II	III	IV	VIII	Total
59.....	—	1	6	—	7
58.....	7	86	132	4	229
57.....	14	229	262	14	519
56.....	1	46	31	—	78
55.....	—	—	1	—	1
No.....	22	362	432	18	834
M	57·273	57·116	57·257	57·222	57·195
m	±0·114	±0·032	±0·029	±0·099	±0·021

Summer Spawners.

No. of V / Mat. Stage	II	III	V	VII	VIII	Total
59.....	1	—	—	—	1	2
58.....	70	—	—	—	20	90
57.....	363	—	1	1	115	480
56.....	91	1	—	—	48	140
55.....	3	—	—	—	2	5
No.....	528	1	1	1	186	717
M	56·953				56·839	56·922
m	±0·025				±0·047	±0·022

No. of V	Otolith Type							
	SA	SB	SC	SD	Total S	VA	VB VC	Total
59	—	1	1	—	2	4	3	7
58	51	17	8	30	106	143	112	255
57	276	108	74	134	592	317	230	547
56	66	30	19	32	147	52	30	82
55	2	—	1	2	5	1	1	2
No. ...	395	156	103	198	852	517	376	893

	SA	SB	SC	SD	Total S
M ...	56·952	56·930	56·893	56·970	56·945
m ...	± 0·028	± 0·045	± 0·052	± 0·042	± 0·019

	VA	VB VC	Total V
M ...	57·188	57·229	57·205
m ...	± 0.027	± 0·031	± 0·020

respectively. As in the previous periods, the vertebral numbers prove, as far as is possible by this method, that the otolith types are correctly defined as to race.

The final result of our race analysis during this period is expressed in the following figures:

No. of V	Summer Spawners	Spring Spawners	Total
59.....	2	7	9
58.....	106	255	361
57.....	592	547	1139
56.....	147	82	229
55.....	5	2	7
No.....	852	893	1745
M	56·945	57·205	57·078
m	± 0·019	± 0·020	± 0·019

c) Age Distribution.

The same year-classes dominate the samples as in the previous period. The age distribution and the percentages of the two races, respectively, are shown in the graphs Fig. 8.

E. Review of Results.

In the following table a survey is given of the vertebral numbers of the different otolith types.

No. of V	Otolith Type							
	SA	SB	SC	SD	Total S	VA	VB VC	Total V
59 ..	1	3	1		5	12	8	20
58 ..	215	109	38	96	458	395	325	720
57 ..	1078	534	256	418	2286	829	607	1436
56 ..	290	128	63	110	591	109	80	189
55 ..	6	2	2	3	13	4	1	5
54 ..	1	1			2			
No. .	1591	777	360	627	3355	1349	1021	2370

	SA	SB	SC	SD	Total S
M ...	56·945	56·974	56·925	56·968	56·959
m ...	± 0·015	± 0·021	± 0·029	± 0·024	± 0·010

	VA	VB VC	Total V
M ...	57·223	57·253	57·237
m ...	± 0·017	± 0·022	± 0·012

The otolith types cannot be strictly defined, and therefore they should not be taken too literally, as they are based on a subjective estimate. No biological significance is at present assigned to these types, they have only served the useful purpose of giving an idea of the extent of variation in the characteristics that distinguish the seasonal races. Only two of the types are more strictly defined, i. e., the typical SA and VA types. The author's estimate of the others may have varied considerably in the course of the investigation, and this is indeed indicated when we consider the percentage frequencies of the various types, which are shown in the following table:

Type / Period	1st	3rd	4th	Total
SA	53·8	**46·3**	**46·4**	47·4
SB	18·5	26·3	18·3	23·3
SC	13·3	9·6	12·1	10·7
SD	14·4	17·8	23·2	18·7
VA	64·5	**56·2**	**57·8**	56·8
VB VC	35·5	43·8	42·2	43·2

It will be seen that the types which could be more exactly defined, i.e., SA and VA, show practically the same percentages in the 3rd and 4th period, i. e., the relation between the typical and atypical otoliths seems to be the same in the two periods. During the analysis of the 1st period the author was less experienced in distinguishing the types and the numbers investigated are also smaller than in the two other groups. There is a similar trend in the figures given for the atypical S types, and the differences are probably due to varying estimates of the different types.

A significant difference is found between the frequency of the VA type in the Norwegian and the southern Icelandic spring herring. The atypical otoliths are more frequent in the Icelandic herring comprising, 43·2% of the total as against 14·4% in the Norwegian herring. No explanation of this phenomenon is offered at present. Further investigations may reveal if the higher mean vertebral number of the atypical V types has any significance, indicating that these types have hatched at somewhat lower temperatures. The later spawning of the Icelandic herrings may also, perhaps, have something to do with the appearance of the otolith nuclei. But these questions will not be considered further on this occasion.

We have now succeeded in dividing our whole collection according to seasonal race and we obtain the following vertebral numbers:

No. of V	Summer Spawners	Spring Spawners	Total
59	7	22	29
58	597	810	1407
57	2941	1627	4568
56	749	217	966
55	17	5	22
54	3	—	3
No.	4314	2681	6995
M	56·959	57·234	57·064
m	±0·009	±0·015	±0·007

For comparison with this result we have data at our disposal which show the number of vertebrae in the Faxa Bay herring caught in February 1947, Nov.—Febr. 1947—48 and Oct.—Dec. 1948. These herrings are thus caught at that time of the year when maturity stages are indicative of the race. These data are compiled from Fridriksson (1949) Table 18, p. 42. The following vertebral numbers are noted:

No. of V	Summer Spawners	Spring Spawners	Total
59	12	27	39
58	468	634	1102
57	1909	1297	3206
56	546	182	728
55	18	5	23
54	5	5	10
53	2	—	2
No.	2960	2150	5110
M	56·962	57·224	57·072
m	±0·012	±0·014	±0·009

It will be seen that the mean vertebral numbers are practically the same as found in our survey.

The Change in Maturity during the Period of Investigation.

Samples taken at suitable intervals have been selected for the construction of the two graphs shown in Fig. 9. These graphs show the percentages of the different maturity stages in the two seasonal races during the period of investigation.

The upper graph shows the conditions in the spring

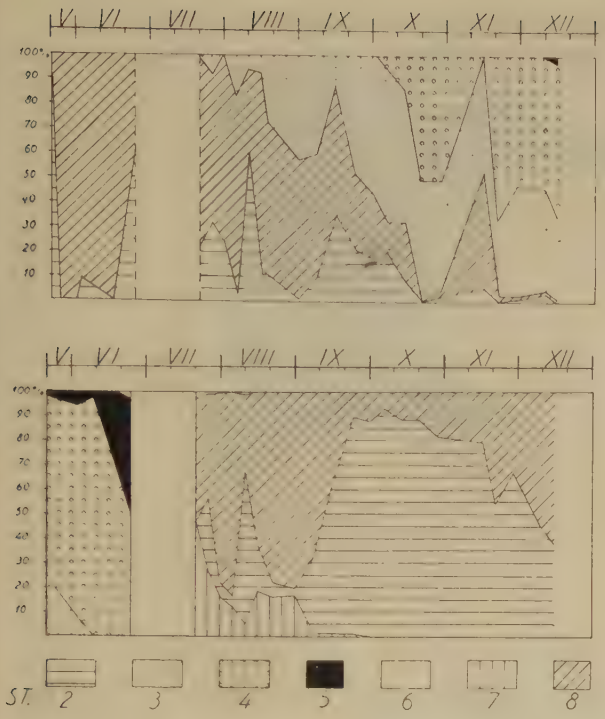


Fig. 9. Percentage frequency of maturity stages during the period of investigation. St. 2–8 = Maturity stages II–VIII (see page 56).

spawning stock. In May, June and July this stock is in maturity stages VIII and II, the individuals being immature or recovering spents. In August and September an increasing proportion of these individuals develop to stage III and in the beginning of October almost all have reached stage III or IV (sample 33/49 being an exception, as it contains less developed individuals than normally found at this time of the year). In December the first individuals in maturity stage V appear. From investigations carried out during January and February 1947 and 1948 (Friðriksson 1949, p. 42) we know that in these months stages IV and V dominate until the herrings disappear from the Faxa Bay and go to the spawning grounds, which the present author found were mainly west of the Vestmannaeyjar during the spring of 1948. Here spawning occurs in March, the small fry appearing in the catches made in the beginning of April. During April the spring spawners are probably mainly in stage VII or VII—VIII, and from May onwards our graph gives information on the further development.

The development of the gonads in the summer spawning stock is shown in the lower graph. During May and June the summer spawners are rapidly developing their sexual products, the individuals being in stage III, IV and V in these months. The first signs of spawning appear at the end of June, the main spawning occurring in the first half of July. During the spawning period the herring disappear from the upper water layers of the sea and are not caught in the drift-nets.

In the latter half of July they appear again, and now they are in stages VII and VIII. Our investigations indicate that a new influx of immature summer spawners occurs during September, for stage II becomes dominant in that month. These individuals become gradually more developed, and an increasing proportion is noted as stage VIII, which may also be defined as stage II—III, as discussed above. The further development of the summer spawners is at present not known. However, in the period from the middle of December to the latter half of May the stock develops from stage VIII or II—III, through stage III to stages IV and V which are found in May as previously shown.

A comparison between the two graphs shows that in the period July to October both seasonal races are in the same stages of maturity, i. e., II and VIII, and during this period the maturity stages cannot be used for the purpose of race discrimination. Unfortunately a large part of the Icelandic herring material is obtained at this time of the year, while the summer fishing is going on.

The Mixing of Seasonal Races in Southern Icelandic Waters.

A. Units of the Herring Population.

When the percentages of the two respective races had been calculated, it was at once obvious that the races occurred repeatedly in approximately the same proportions. The percentage figures are given in Fig. 8. We can distinguish between the following groups:

1. 12 % spring spawners: 88 % summer spawners.

6 samples belong to this group, all taken in Jökuldjup, on the following dates— May 23rd (15:85) and June 2nd (13:87), 3rd (14:86), 9th (10:90), 10th (12:88) and 11th (10:90).

2. 3 % spring spawners: 97 % summer spawners.

This composition was found twice only, but curiously enough in exactly the same area (the inner part of Faxa Bay) with an interval of two months. The first time it was found north of Syðra Hraun on June 23rd (3:97), the catch being taken in the trawl. Some of the summer spawners were beginning to spawn at that time. The second time it was encountered, was off Þormoðssker on August 23rd (3:97).

3. 36 % spring spawners: 64 % summer spawners.

This mixture was found 7 times, all the catches being made in Jökuldjúp. The dates of capture and

Fig. 10. Icelandic localities mentioned in the text.

the percentages were: July 25th (39:61), 26th (38:62), 29th (35:65) and August 3rd (38:62), 9th (33:67), 13th (35:65) and 15th (34:64).

4. 55 % spring spawners: 45 % summer spawners.

This mixture was found twice in Jökuldjúp, on July 30th (52:48) and August 5th (55:45). It also occurred twice in Grindavíkursjór, viz. on August 17th (57:43) and 31st (55:45).

5. 25 % spring spawners: 75 % summer spawners.

This composition was encountered 5 times. With the exception of the last catch, which was taken off Garðskagi and differs considerably as regards maturity stages and size of the individuals, the others were all taken in Jökuldjúp. The dates and the percentages were as follows: September 15th (22:78), 23rd (26:74), 30th (28:72) and lastly November 16th (21:79).

6. 63 % spring spawners: 37 % summer spawners.

This mixture was found 8 times. It was first encountered off Eldey on May 20th (61:39), then far off shore, 54 naut. miles west of Malarrif on July 21st (67:33). In Grindavíkursjór it was found twice, on September 7th (63:37) and October 27th (63:37). Then again it was the sole component found in the Miðnessjór-area, from the beginning of the fishery in that area on November 21st until the fishery ended because of bad weather in the middle af December. In Miðnessjór the samples were taken on November 21st (64:36), 28th (66:34) and December 9th (59:41) and 15th (63:37).

7. Not referable to a certain group.

When the above six divisions have been made, only 3 samples are left, and these do not fall easily into any of the categories. Two of them have a similar composition, both containing a high percentage of spring spawners and both taken in Grindavíkursjór. One was taken on September 8th (81:19) and the other on October 19th (72:28). These samples resemble most the mixture 63:37, found in the same area in the same months. On the other hand, they may represent elements not otherwise encountered during the investigation.

The third sample, not referable to a certain group, has the composition 17:83, and was taken in Jökuldjúp on October 13th. It is most similar to the mixture 25:75 found in Jökuldjúp in the same period.

It should be explained that these three samples were all taken outside the period when the otoliths were the sole criteria in the racial analysis.

It is quite evident that all these apparently fixed mixtures of the two races represent definite units of the herring population. These units were neither anticipated nor expected, but were discovered when the whole material was analysed according to race, maturity and age, and it will be seen that they are mostly restricted to a certain area during a certain period. The unit 63:37, however, was found at odd times throughout the whole period of investigation and in widely separated localities.

It is also noteworthy that the mixtures are ex-

Spring Spawners.

Unit / Rings	2	3	4	5	6	7	8	9	10	11	12	13	Total	N
12:88	—	—	18·9	48·7	2·7	4·1	2·7	2·7	16·2	0·7	2·0	1·3	100·0	148
3:97	—	—	76·9	15·3	7·7	—	—	—	—	—	—	—	99·9	13
36:64	—	0·4	66·0	29·8	2·9	0·4	0·2	0·2	—	—	—	—	99·9	446
55:45	—	—	61·8	32·2	3·6	0·7	1·0	—	0·7	—	—	—	100·0	419
25:75	—	—	86·6	11·9	1·1	—	0·4	—	—	—	—	—	100·0	261
63:37	—	0·9	74·9	22·0	1·4	0·4	0·2	—	0·1	—	—	—	99·9	1065

Summer Spawners.

Unit / Rings	2	3	4	5	6	7	8	9	10	11	12	13	14	15	N
12:88	—	0·9	62·5	19·5	6·1	4·3	2·4	0·6	2·2	—	0·8	0·2	0·4	0·1	1046
3:97	—	4·4	73·5	16·1	2·5	2·1	0·6	0·2	—	—	0·4	—	—	—	472
36:64	—	2·5	64·7	22·1	5·7	3·8	0·9	—	0·3	—	—	—	0·1	—	796
55:45	—	2·3	62·9	23·3	6·0	4·0	1·2	—	0·3	—	—	—	—	—	348
25:75	—	5·9	81·3	10·8	1·4	0·2	0·4	—	—	—	—	—	—	—	783
63:37	0·3	6·7	64·7	20·9	3·2	2·3	1·1	0·3	0·3	—	—	—	—	—	618

ceedingly uniform as regards age composition. On the other hand, there are certain differences in the age distribution between the various units, as will be seen from the above table, which shows the percentages of the various age-groups.

It will be noticed that there is a certain parallelism between the strength of the broods of spring and of summer spawners. This will be evident when we compare the percentages of the 4-ringers for example. An exception is the unit 12:88 where the spring spawners have the 5-ringers as a dominating component. The 25:75 unit has an unusual high percentage of 4-ringers in both races.

When the units are tested as to vertebral number we get the following mean numbers:

Unit..	12:88	3:97	36:64	55:45	25:75	63:37
			Spring Spawners			
N	148	—	446	419	261	1065
M	57·277	—	57·224	57·286	57·195	57·204
m	±0·050	—	±0·028	±0·028	±0·038	±0·019
			Summer Spawners			
N	1042	476	798	348	783	618
M	56·979	56·905	56·964	56·971	56·960	56·979
m	±0·018	±0·028	±0·022	±0·030	±0·019	±0·024

These mean numbers do not indicate any significant difference as regards the vertebral number of the different units.

B. Review of Results.

When we consider the observations recorded in the foregoing it is possible to outline the sequence of events taking place in the herring population inhabiting the south-western coastal waters of Iceland during the period of investigation.

The drift-net fishery starts at the end of May in Jökuldjúp, which is inhabited by a herring population consisting of approximately 12% spring spawners and 88% summer spawners. The summer spawners are rapidly developing their genital products. The dominant age-group among the spring spawners is the year-class 1944, i. e., 5-ringers, but among the summer spawners the 4-ringers, i. e. year-class 1944, are the most numerous. As the summer spawning period draws nearer, this population disappears and the drift-net fishery comes to an end.

An accidental trawl catch, made on 23rd June, consisted almost entirely of summer spawners.

When the drift-net fishery is resumed a month later, and the summer spawning is in the main finished, Jökuldjúp is inhabited by a different population, of which the spring spawners constitute about 36% and the summer spawners about 64%. The 4-ringers dominate in both races, i. e. year-classes 1945 and 1944. Together with this unit, another, containing a greater percentage of spring spawners (55:45), is also found and, towards the close of August the fishing shifts over to Grindavíkursjór, where this same unit is now found. These two units (36:64 and 55:45) are also similar from the point of view of age distribution, as will be seen from the table given above.

When the fishery is resumed in Jökuldjúp in the middle of September, we encounter an entirely different population there (25:75). Besides the percentages of the two respective races, we also notice that the 4-ringers constitute more than 80% of both races, and a large part of the summer spawning race is in maturity stage II (vide Fig. 9), i. e., consists of individuals that have not previously spawned.

In September and October the fishing goes on both in Jökuldjúp, where the 25:75 unit is found, and also in Grindavíkursjór, where we encountered the 63:37 unit, and perhaps another containing a still greater percentage of spring spawners (vide group 7, p. 70).

On 20th November the fishing is finished in Grindavíkursjór, but it is resumed the following day, 21st November, in Miðnessjór. Here we encounter the 63:37 unit again. The majority of the summer spawners in this unit are also immature, while the spring spawners are mostly in maturity stages III and IV.

We may also briefly consider the connection between the units and certain fishing areas.

Jökuldjúp. This area, in May and June, is populated by the 12:88 mixture. In July and August we have mainly the 36:64 mixture, but twice we encounter the 55:45 unit. In the middle of September we find the 25:75 unit.

The inner parts of Faxa Bay. Within an interval of two months we twice found here the 3:97 unit.

Grindavíkursjór. The relative strength of the spring spawners was always greater in this area than in Jökuldjúp. We found the 55:45 unit in the latter half of August. In September and October the 63:37 unit was encountered, the spring spawners dominating up to 72 and 81 % in samples not referable to a certain group.

Miðnessjór. This area was exclusively inhabited by the 63:37 unit.

Off shore areas. The 63:37 unit was also found on two occasions farther from land, i. e., off Eldey and 54 naut. miles off Malarrif.

At present it is not possible to say whether these recurring mixtures represent an essential feature in the distribution of the herring population. We have only established the fact that these units exist at least for a period of time. It is probable that there is some connection between the shoaling behaviour of the herring and these fixed units. Perhaps a shoal of herring has a certain composition indicated by the percentages that characterize the different units. With the disappearance of one shoal and the arrival of another the composition, with regard to race alters, and other differences may also be observed, e. g., totally different maturity stages.

The fishing area lies on the fringes of a prolific system of oceanic currents. The age distribution, size and maturity indicate that the herrings are partly in that little known phase that Lea called the "oceanic stage", and which he, with real genius, defined even before fishermen or scientists had caught these herrings in their nets (Lea 1928). This subject will be treated more fully in a later paper.

A regularity in the composition of the herring population in Icelandic waters has been fully shown. It remains to point out that this result is an indirect proof of the reliability of the otolith method of race discrimination. The method has thus already proved its value.

Summary.

1. The shortcomings of the methods hitherto employed in distinguishing between seasonal races of herring are discussed. An adequate method for identifying immature herrings does not exist and at certain times of the year the usual methods, based on maturity stages and meristic characters, give unreliable or misleading results, even when applied to adult herrings. It is pointed out that these shortcomings render the distinction between the Icelandic summer spawners and spring spawners impossible during the main fishing season in late summer.

2. Distinguishing characters of the Icelandic seasonal races are examined—maturity stages, vertebral numbers and size of the central area of the scales. It is concluded that it is possible to detect the presence of seasonal races by the aid of these characters, but only when the degree of maturity can be used as a distinguishing character.

3. Particular attention is devoted to structural characteristics of otoliths from Norwegian and Icelandic herrings. It is shown that two main types can be distinguished, i. e., otoliths with hyaline nuclei and otoliths with opaque nuclei (Fig. 3 a—c). These structural characteristics are explained as being due to differing seasonal growth conditions during the larval and post-larval life of the herring, summer spawners developing hyaline nuclei and spring spawners opaque nuclei. However, intermediate types occur, and it is pointed out that the main theme of the present paper is the presentation of data showing the range of variation in these characteristics, together with a test made on extensive material of otoliths from the Icelandic herring.

4. Observations of other authors regarding the nuclei of herring otoliths are reviewed and discussed.

5. The variation in the appearance of otoliths from Norwegian spring spawners is examined. The variation is roughly classified into three types, only the first being more strictly defined. The variation is found to be slight, 85·6 % of the otoliths belonging to the typical category.

6. More variation is experienced in the appearance of the otoliths of Icelandic summer spawners. Four otolith types are distinguished, especially the first being well defined; 67·6 % of the otolith samples examined conformed with this type.

7. The difficulties in using the appearance of the otoliths for the purpose of race discrimination are discussed. The main difficulty experienced was the fact that the hyaline area, characteristic for the summer spawners, is frequently covered by opaque material rendering identification difficult. However, it is found that a transverse groove characterizes these otoliths, indicating that a coalescence has taken place. It is maintained that by routine examination the difficult otoliths can be recognized in most cases, but some degree of error must be expected. The results do not indicate that this error is of any significance when adequate collections are available.

8. In order to test the method, a collection, comprising data on 6995 herrings caught in Faxa Bay and adjacent waters, was procured. The period of investigation is divided into four parts.

a) From the latter half of May to the latter half of June the maturity stages are found to be indicative of the race. The collection from this period was prim-

arily used for acquiring the necessary practice in recognising the otolith types. It is shown that the atypical otolith groups of summer spawners have just as characteristic mean vertebral numbers as the typical otolith groups.

b) During the summer spawning, from the end of June to the latter half of July, no herrings were caught in drift-nets.

c) From the latter half of July to the beginning of October, maturity stages cannot be used for racial discrimination. During this period the otoliths only are used when the collection is to be divided according to race. The result is tested by calculating the mean vertebral numbers of the different groups thus distinguished. These mean numbers give strong support to the correctness of the race analysis by this method.

d) From the middle of October to the middle of December good agreement is generally found (one sample being an exception), between the degree of maturity and the otolith type. The test using the means of vertebral numbers, gave the same result as during the third period.

9. The results of the analyses of otoliths are summarized. The various groups distinguished show typical mean vertebral numbers for the two respective races. It is found that in the third and fourth period there is practically the same relationship between typical and atypical otoliths in both races. A significant difference in the frequency of atypical otoliths in the Norwegian and the Icelandic spring spawners respectively is found. These differences are 43·2% in the Icelandic as against 14·4% in the Norwegian spring spawners.

10. A description of the development of maturity in the two races is given. Attention is drawn to difficulties encountered in the determination of maturity stages, especially the stages II—III and VIII.

11. The racial analysis brings out the fact that the races occur repeatedly in approximately the same proportions. With three exceptions the samples could be classified into six groups, each being characterized by a certain mixture of spring and summer spawners. Differences from the standpoint of age distribution and maturity between the groups are discussed. A parallelism between the strength of the broods of spring and summer spawners is found. Generally these population units are found in the same, or neighbouring, fishing areas during a certain period. One such unit was found spasmodically throughout the whole period of investigation. It is suggested that these units have some connection with the shoaling behaviour of the herring. The detection of these units is considered as indirect proof of the correctness of the method employed for distinguishing the seasonal races.

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Appendix.

List of Samples examined.

Sample No.	Date 1949	Locality	Number examined
Norwegian herrings.			
N 1 (5)	31/1	Kvalheimsvåg, Malöy	94
N 2 (7)	2/2	Brennanger	99
N 3 (12)	15/2	Skidnedal, Skudesnes	100
N 4 (13)	22/2	Esjevik, Nedstrand	97
Icelandic herrings.			
1/49	20/5	Off Eldey	271
2/49	23/5	Jökuldjúp	144
3/49	March	Harbour of Akureyri (young herrings)	290
4/49	2/6	Jökuldjúp	238
5/49	3/6	Jökuldjúp	222
6/49	9/6	Jökuldjúp	198
7/49	10/6	Jökuldjúp	168
8/49	11/6	Jökuldjúp	210
9/49	23/6	Syðra Hraun	293
10/49	21/7	54 naut. miles W. of Malarrif	199
12/49	25/7	Jökuldjúp	132
13/49	9/8	Jökuldjúp	199
14/49	13/8	Jökuldjúp	195
15/49	15/8	Jökuldjúp	195
16/49	26/7	Jökuldjúp	163
17/49	17/8	Grindavíkursjór	198
18/49	29/7	Jökuldjúp	160
19/49	30/7	Jökuldjúp	194
20/49	23/8	Off Þormóðssker	196
21/49	3/8	Jökuldjúp	198
22/49	5/8	Jökuldjúp	177

Sample No.	Date 1949	Locality	Number examined
Icelandic herrings.			
23/49	31/8	Grindavíkursjór	198
24/49	7/9	Grindavíkursjór	197
25/49	8/9	Grindavíkursjór	197
26/49	15/9	Jökuldjúp	232
27/49	23/9	Jökuldjúp	235
28/49	30/9	Jökuldjúp	228
29/49	6/10	Jökuldjúp	176
30/49	13/10	Jökuldjúp	196
31/49	19/10	Grindavíkursjór	187
32/49	27/10	Grindavíkursjór	235
33/49	16/11	Off Garðskagi	173
34/49	21/11	Miðnessjór	172
35/49	28/11	Miðnessjór	236
36/49	9/12	Miðnessjór	175
37/49	15/12	Miðnessjór	198

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